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Argyrou

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(54) **METHODS AND APPARATUS FOR CONSTRUCTING MULTI-STOREY BUILDINGS**

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CPC ***E04B 1/34815*** (2013.01); ***E04B 1/34823*** (2013.01); ***E04B 5/04*** (2013.01);
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CPC E04B 1/20; E04B 1/34815; E04B 1/34823; E04B 1/3483; E04B 1/34853; E04B 5/04;
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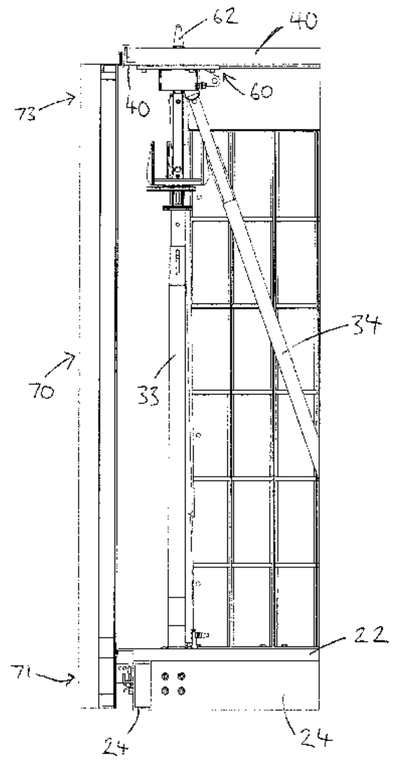
(57) **ABSTRACT**

The invention provides a method of constructing a modular multi-storey building including: assembling first and second building modules in a vertical arrangement at an 5 installation location to form a multi-storey building structure, wherein temporary support members between the first and second building modules vertically support at least part of the second building module above the first building module; installing a permanent support structure 10 and connecting it to the first and second building modules to vertically support the second building module above the first building module; and removing the temporary support members.

20 Claims, 28 Drawing Sheets



(51) **Int. Cl.**

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E04B 2/94	(2006.01)
E04G 11/48	(2006.01)
E04B 1/348	(2006.01)
E04B 5/23	(2006.01)
E04B 5/38	(2006.01)
E04G 21/12	(2006.01)
E04B 5/18	(2006.01)
E04G 11/56	(2006.01)
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CPC ***E04B 5/18*** (2013.01); ***E04B 5/23*** (2013.01); ***E04B 5/38*** (2013.01); ***E04G 11/48*** (2013.01); ***E04G 11/483*** (2013.01); ***E04G 11/56*** (2013.01); ***E04G 21/12*** (2013.01); *E04B 1/20* (2013.01); *E04B 2103/02* (2013.01); *E04C 5/08* (2013.01)

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See application file for complete search history.

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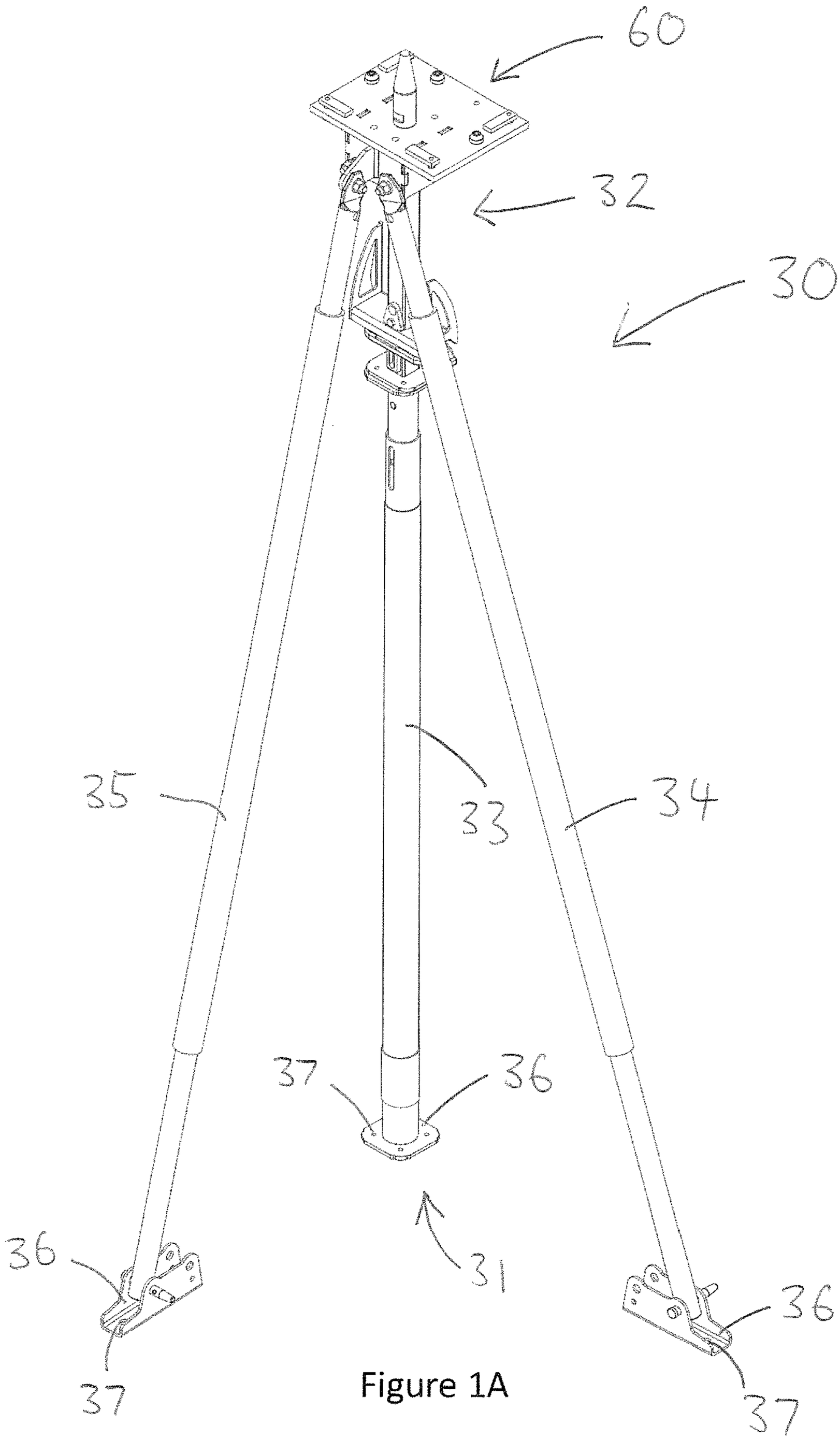

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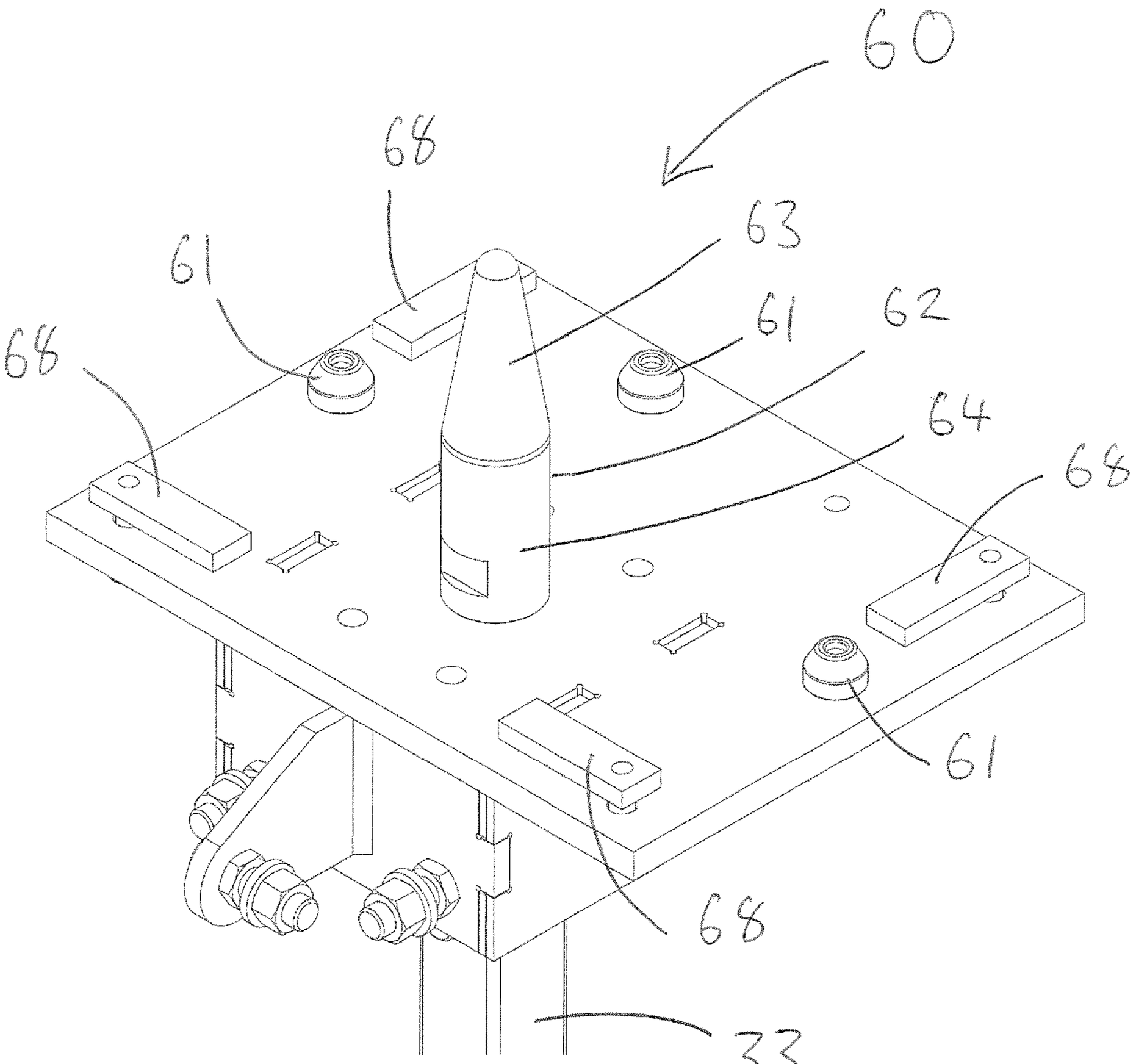

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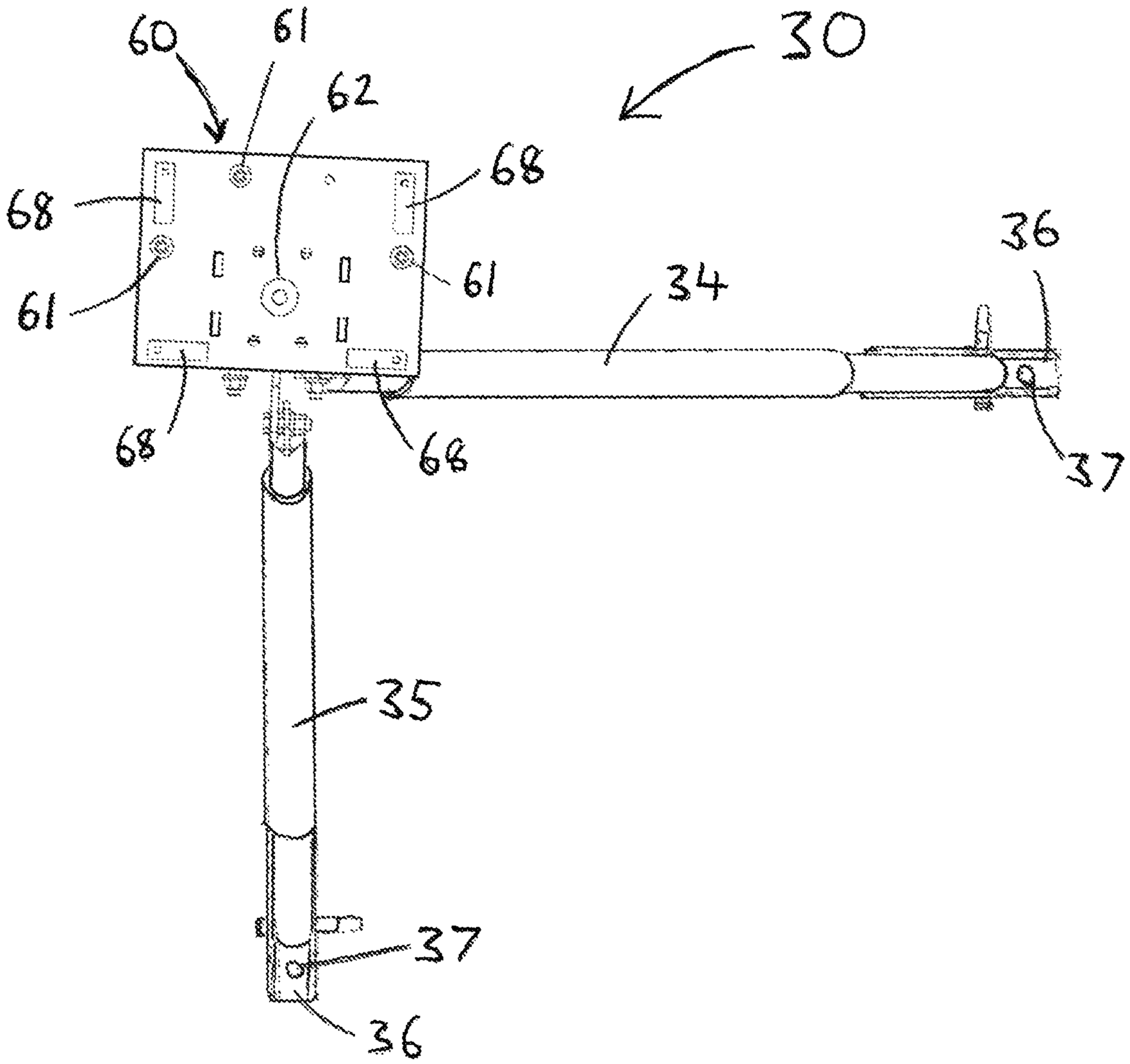

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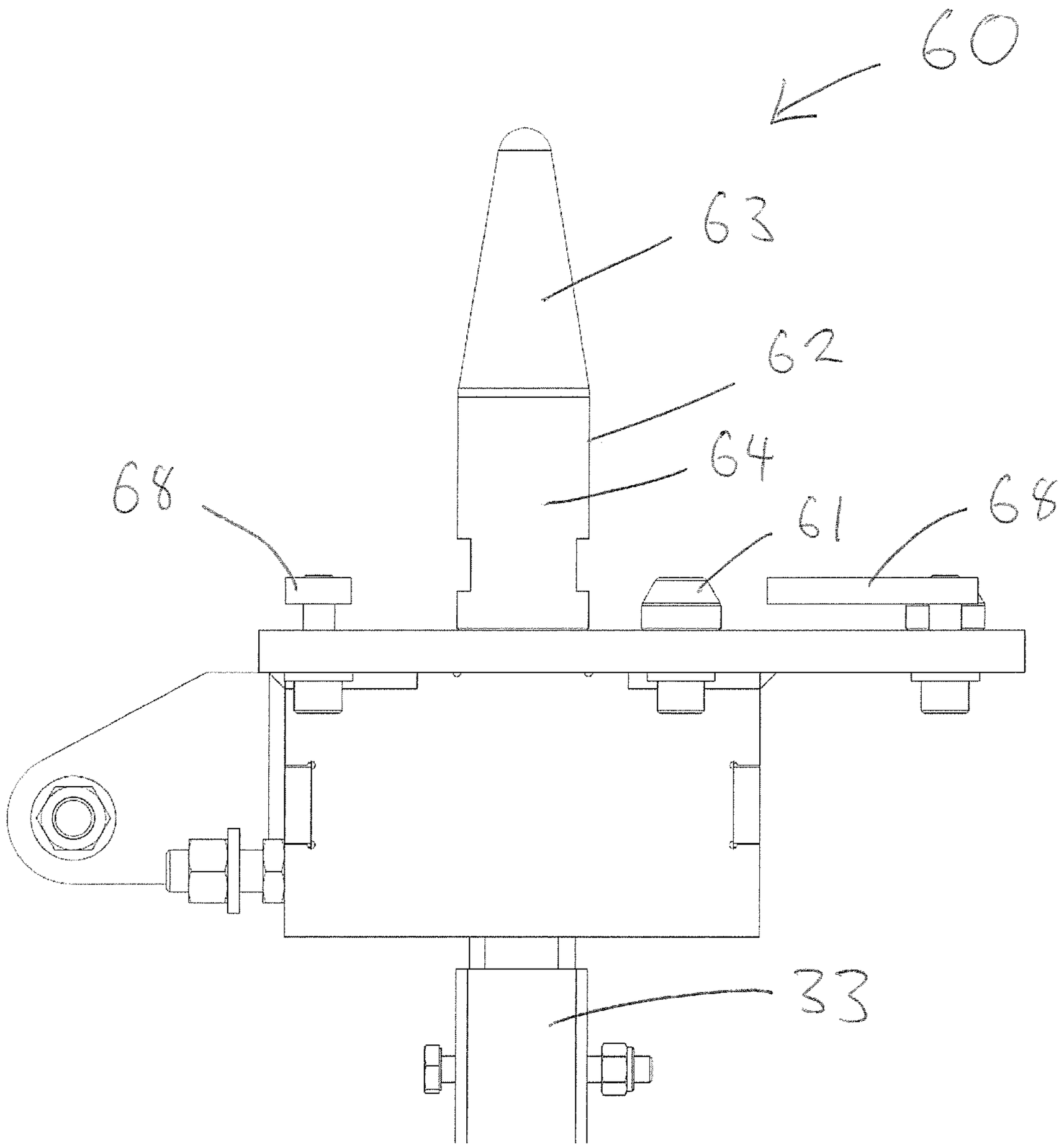

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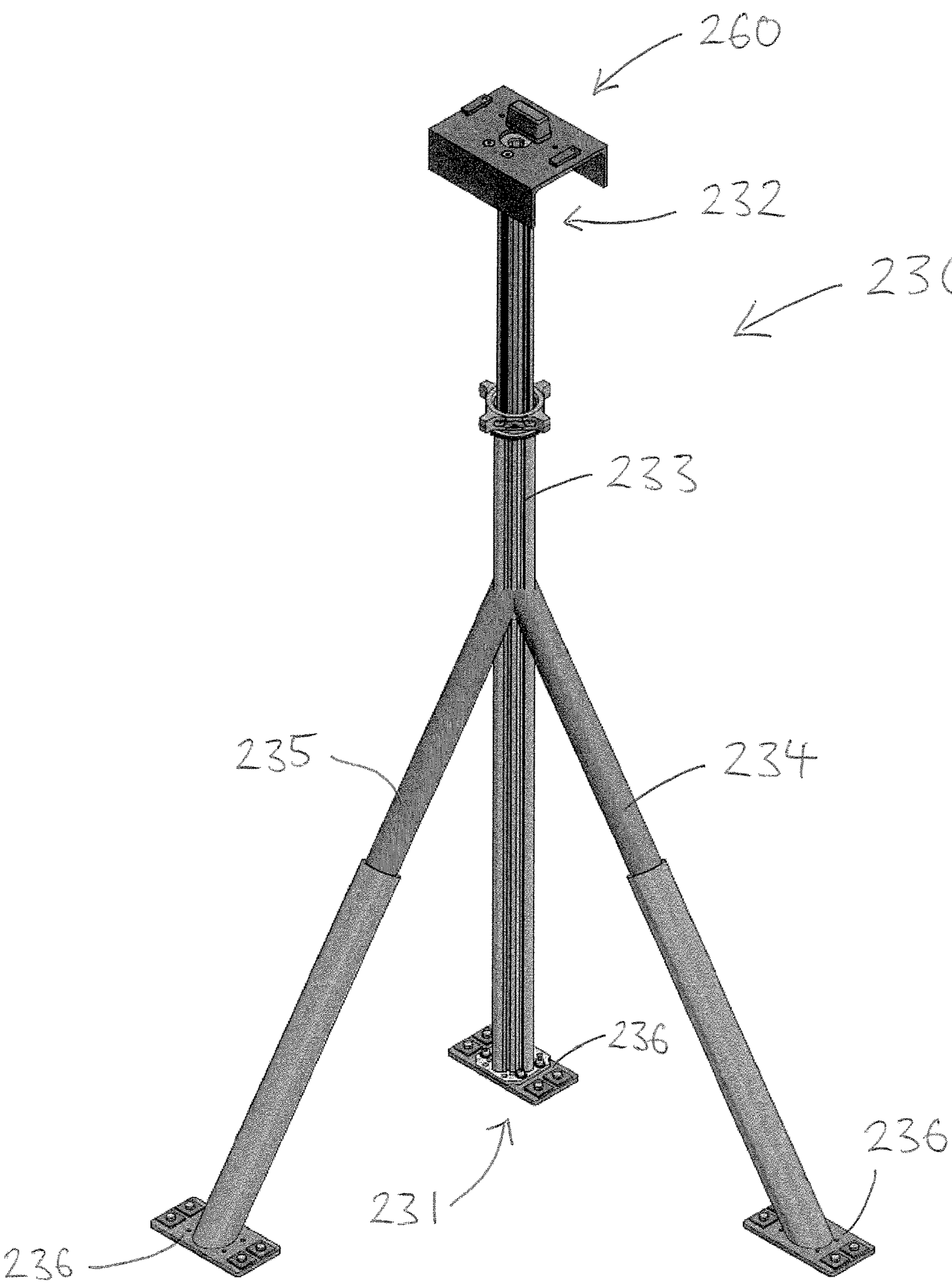

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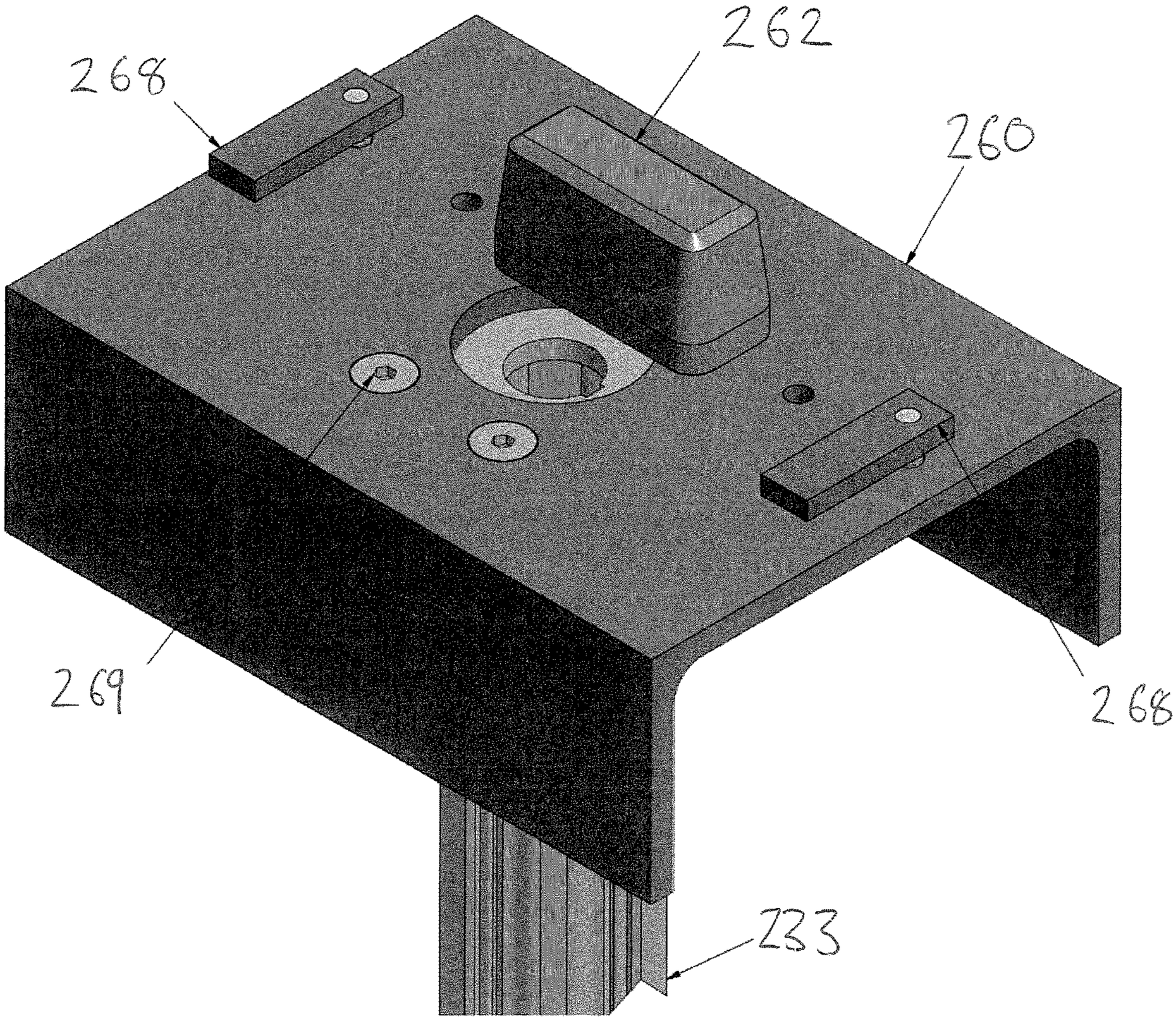

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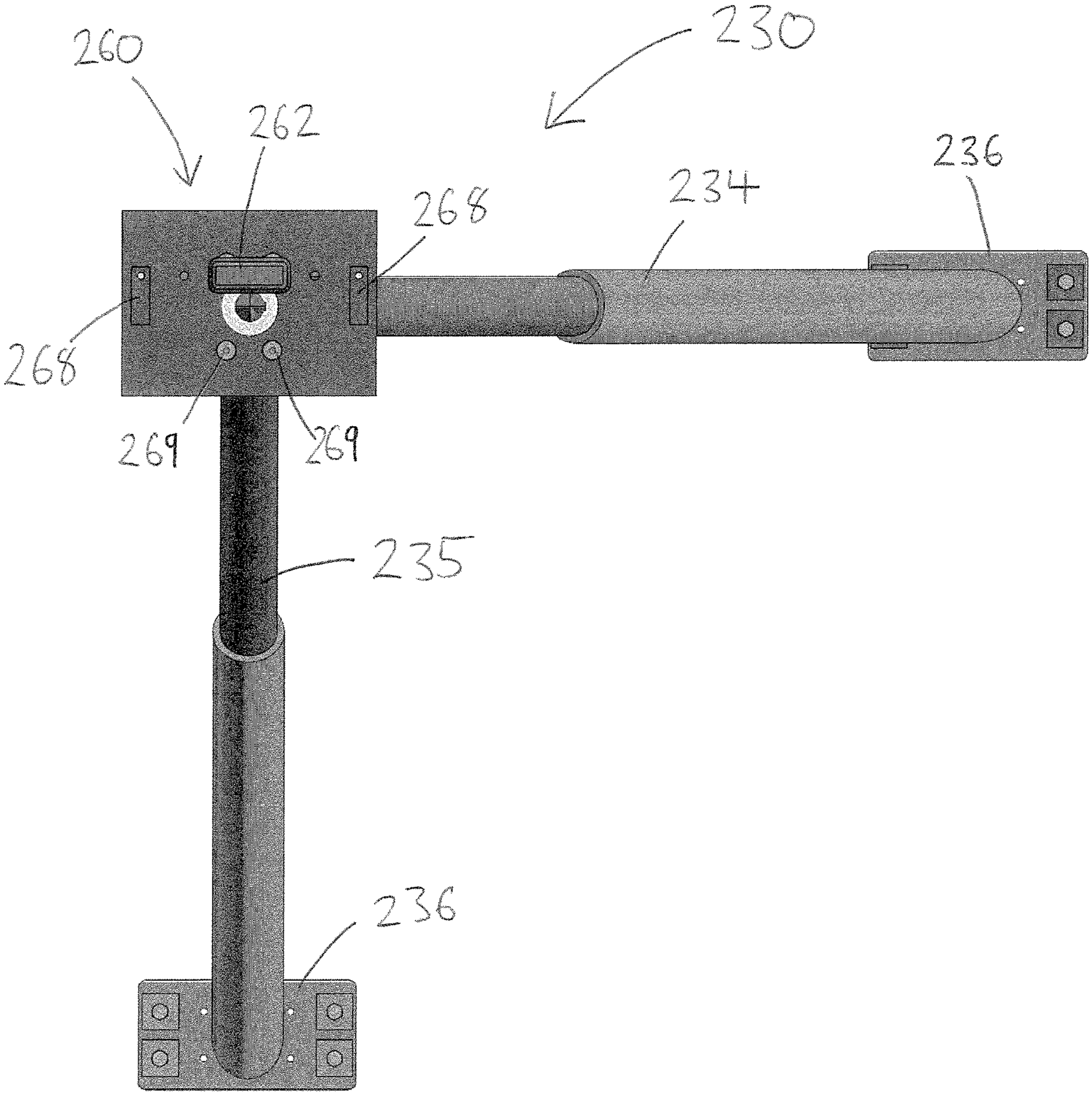

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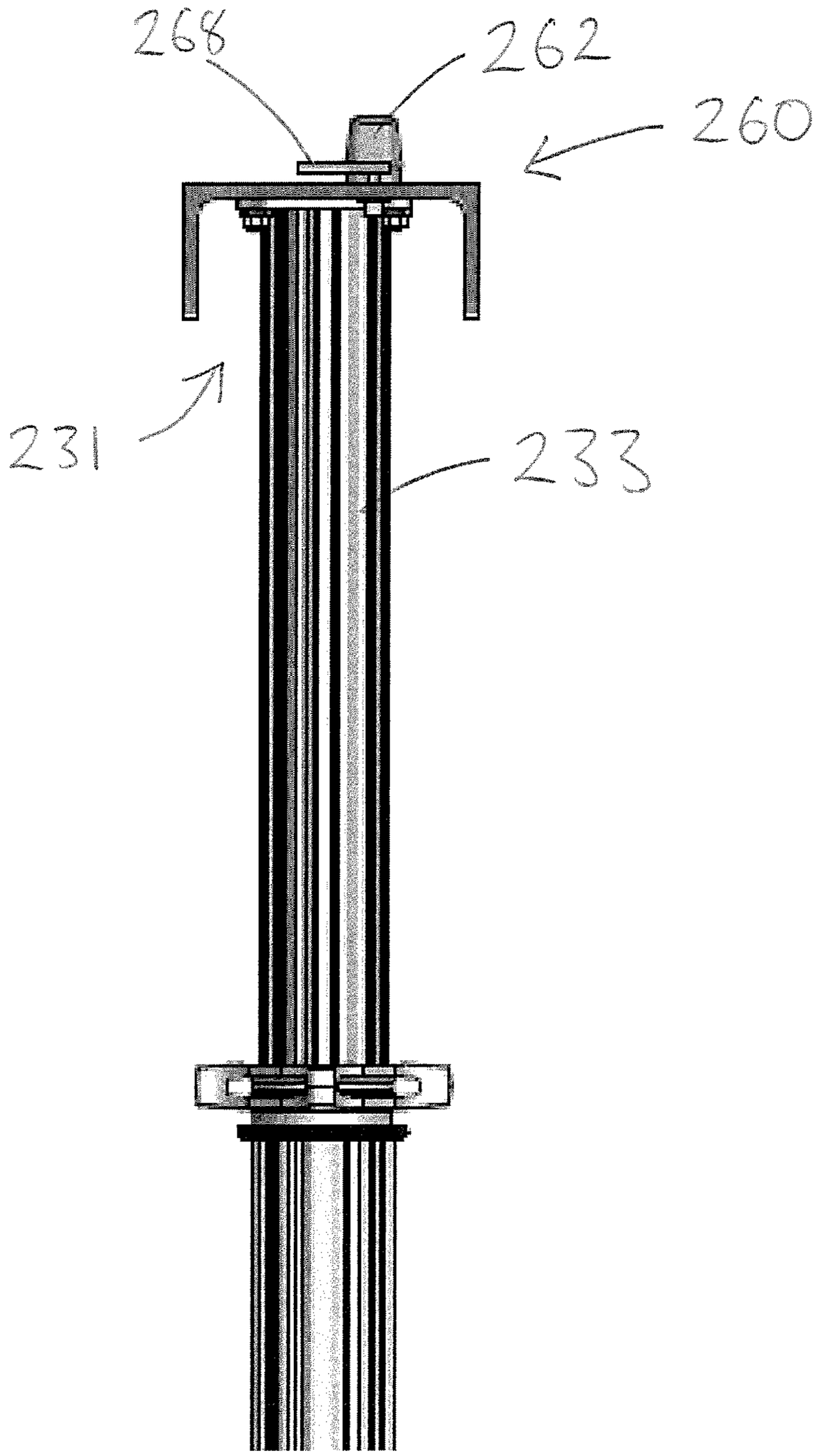

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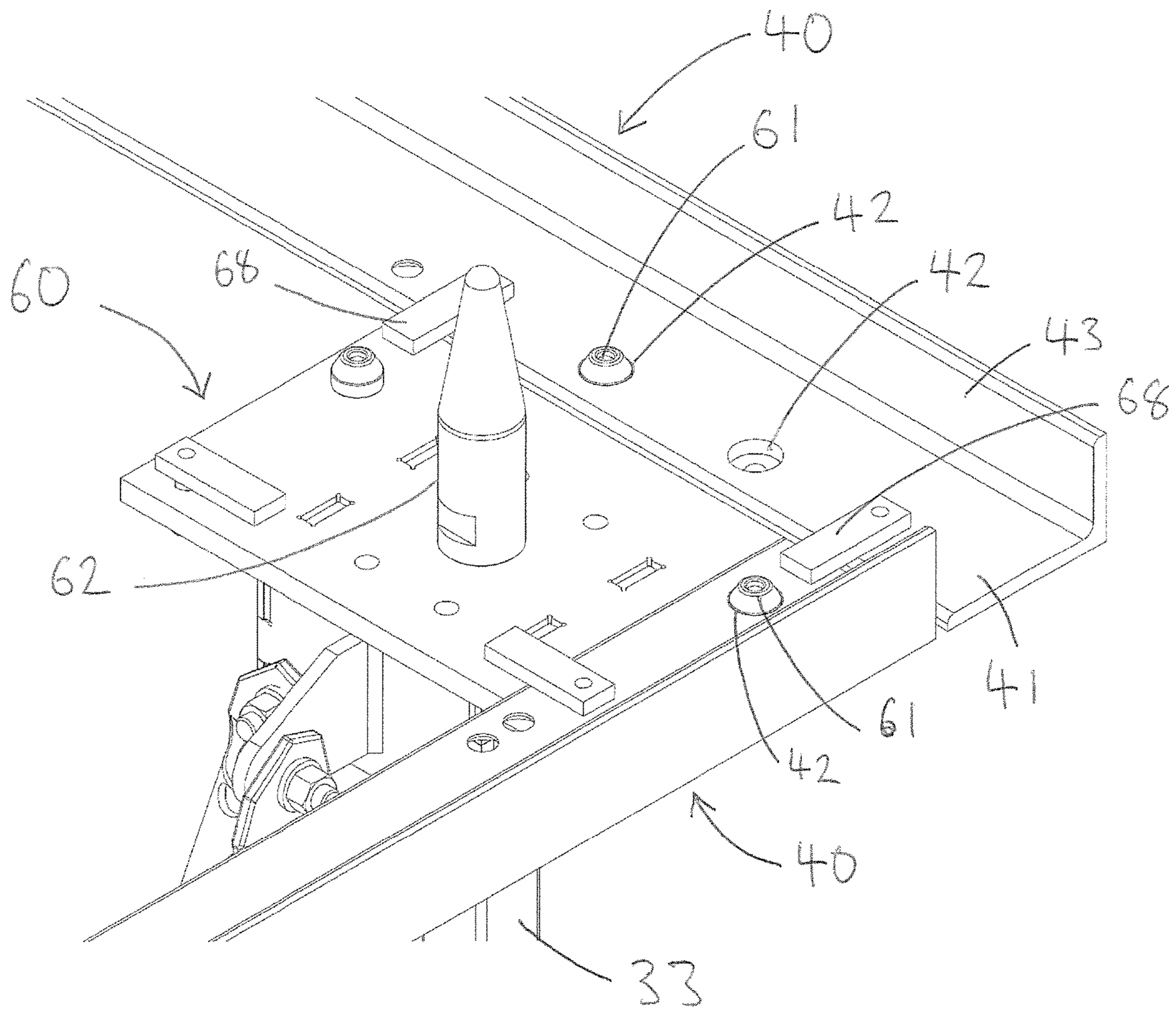

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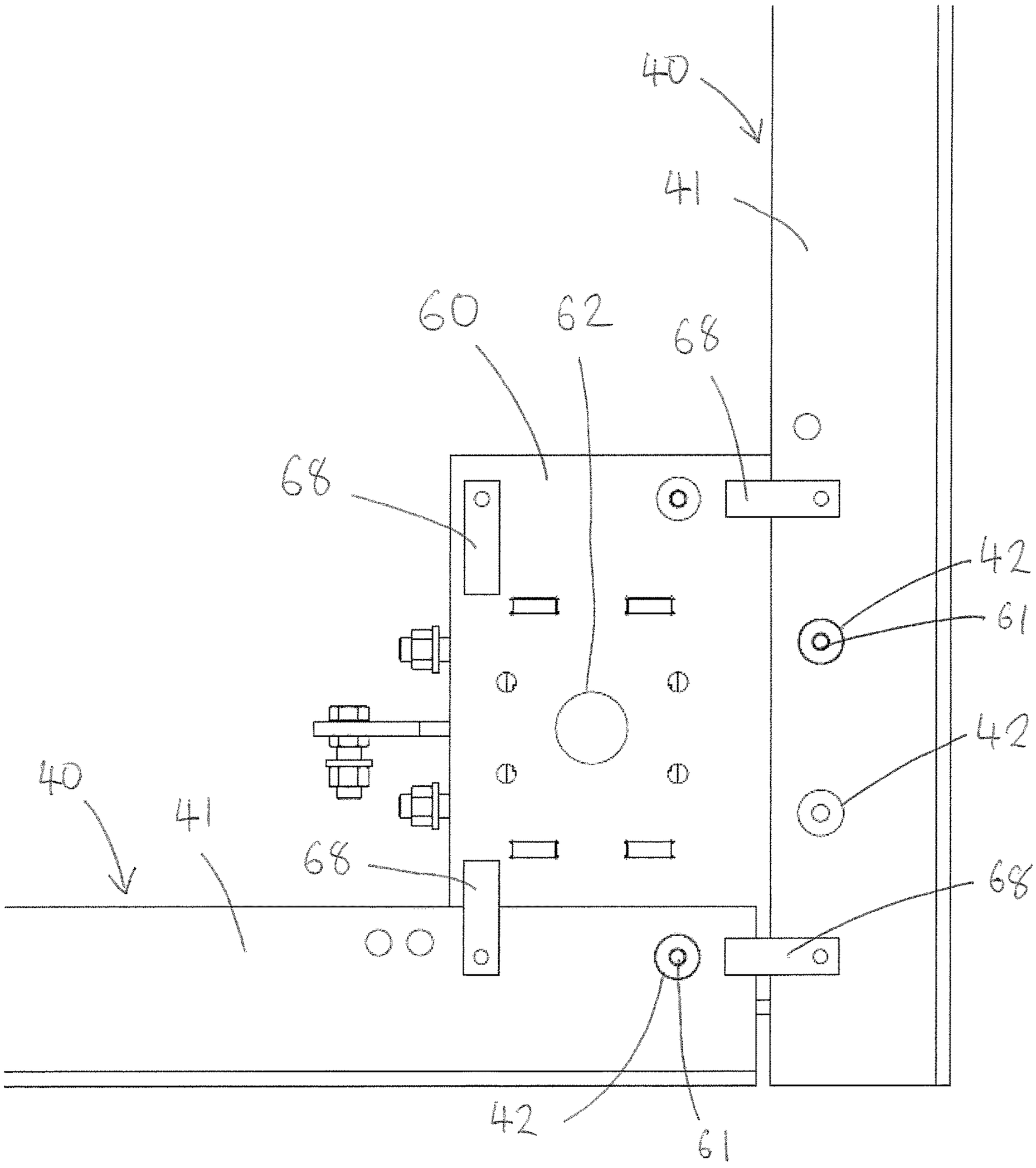

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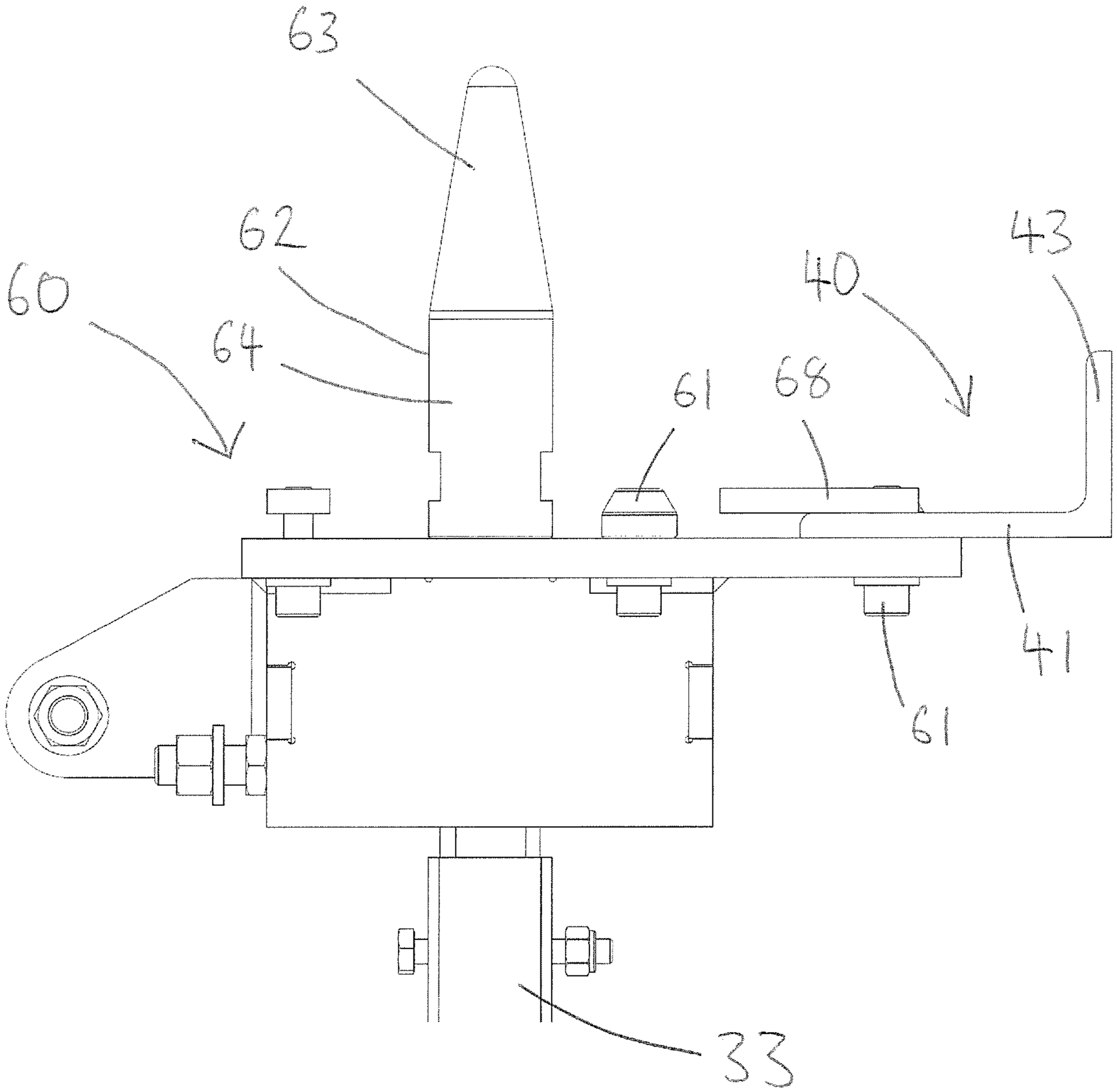

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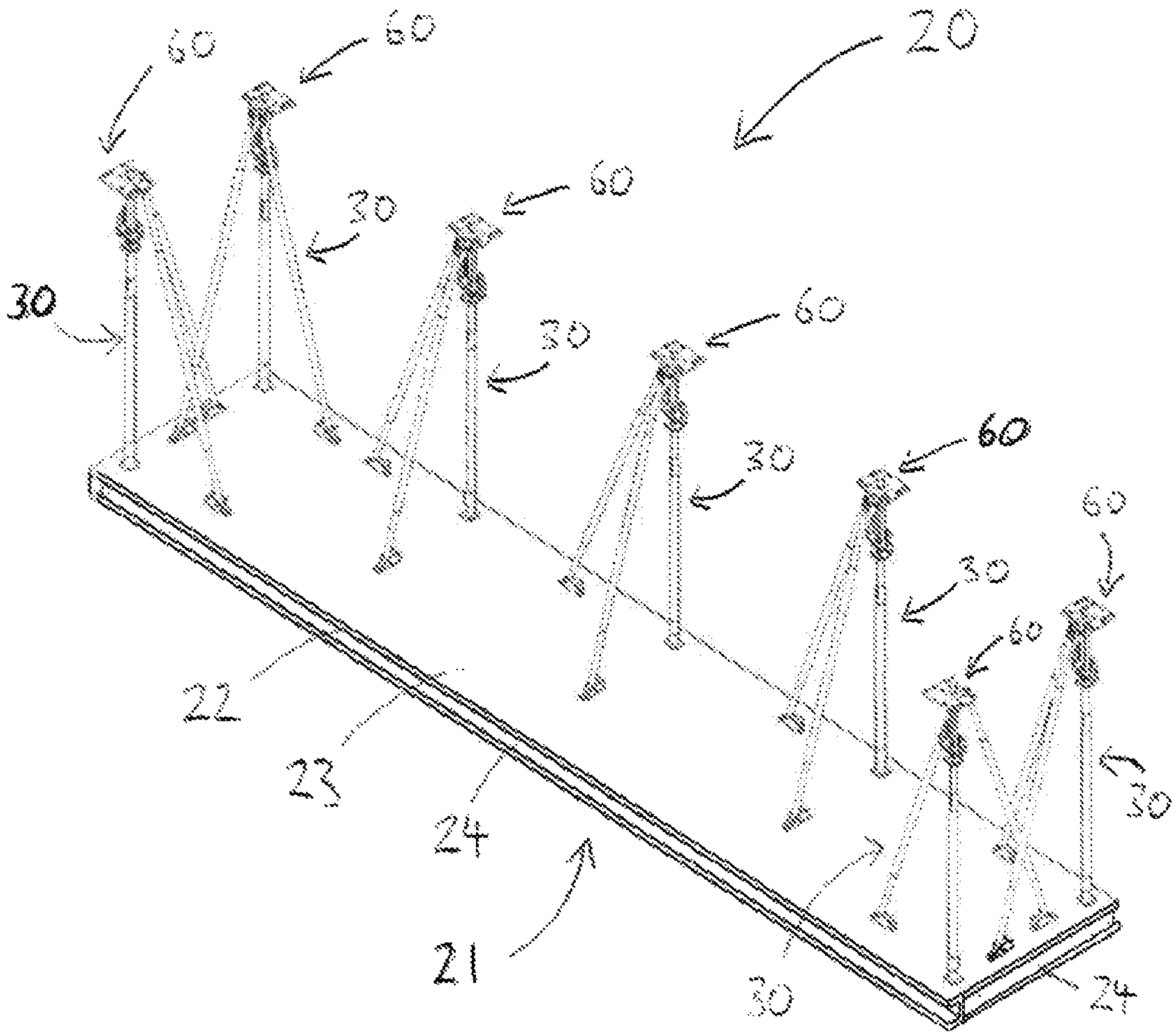

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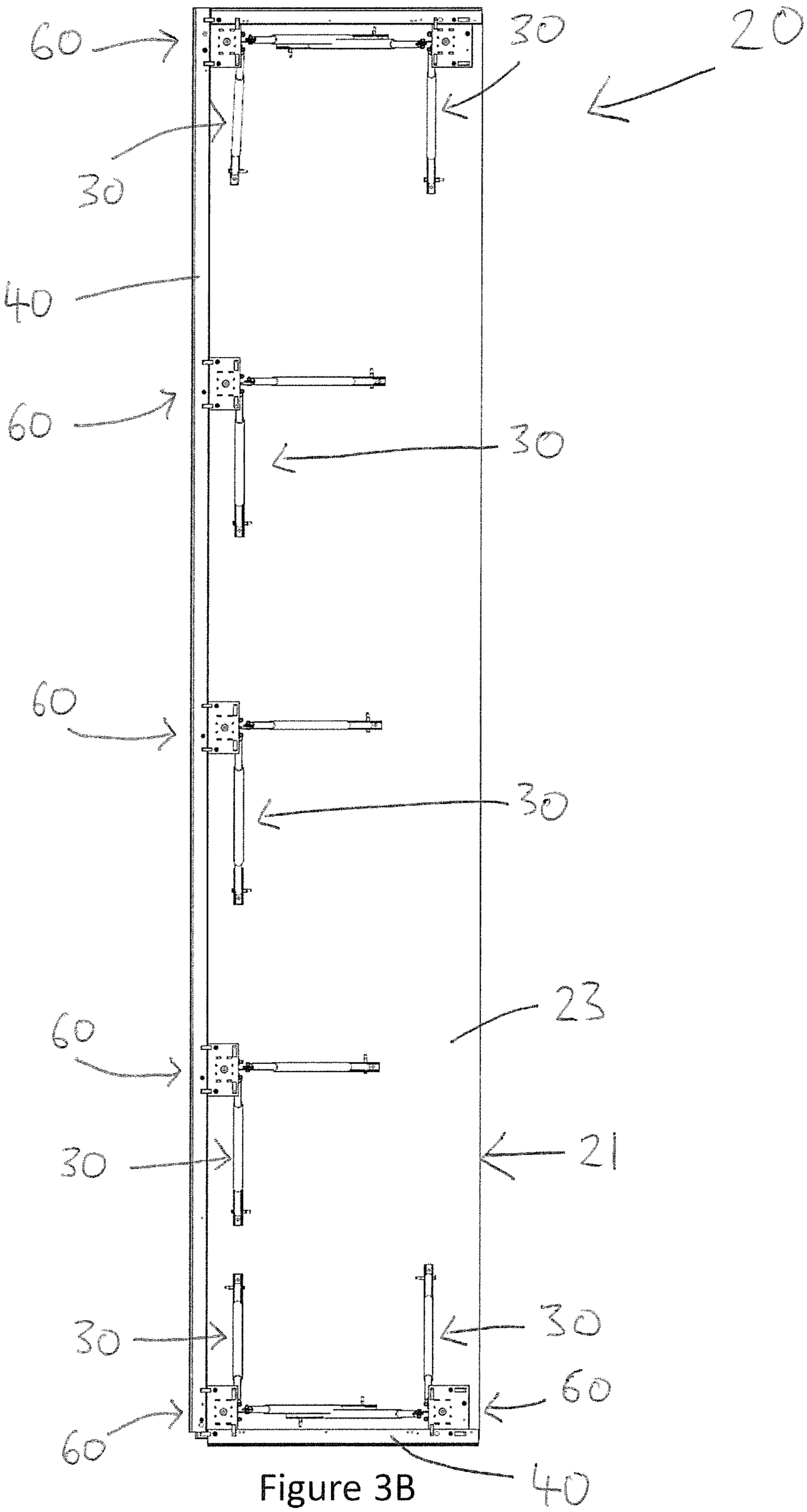

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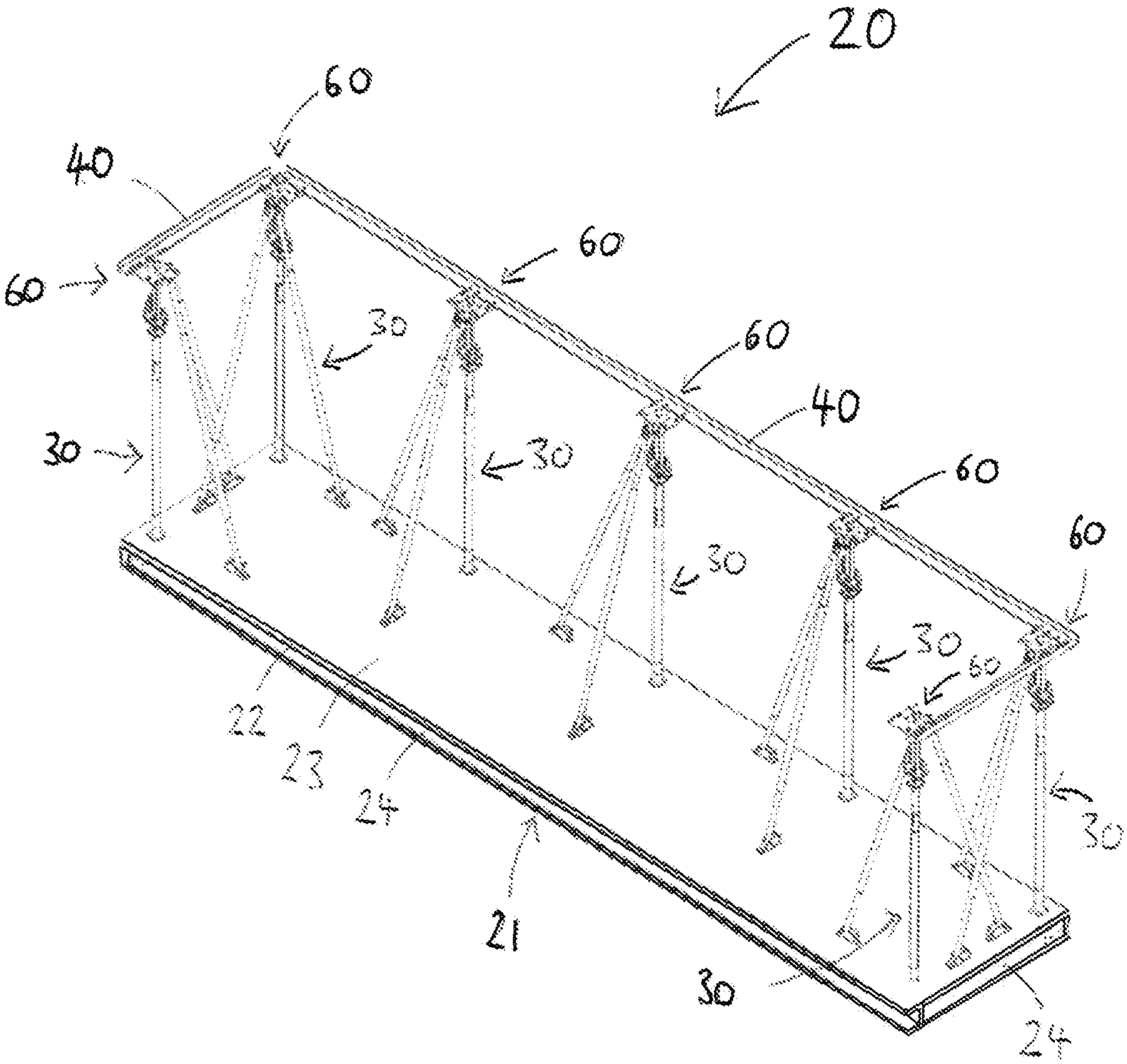

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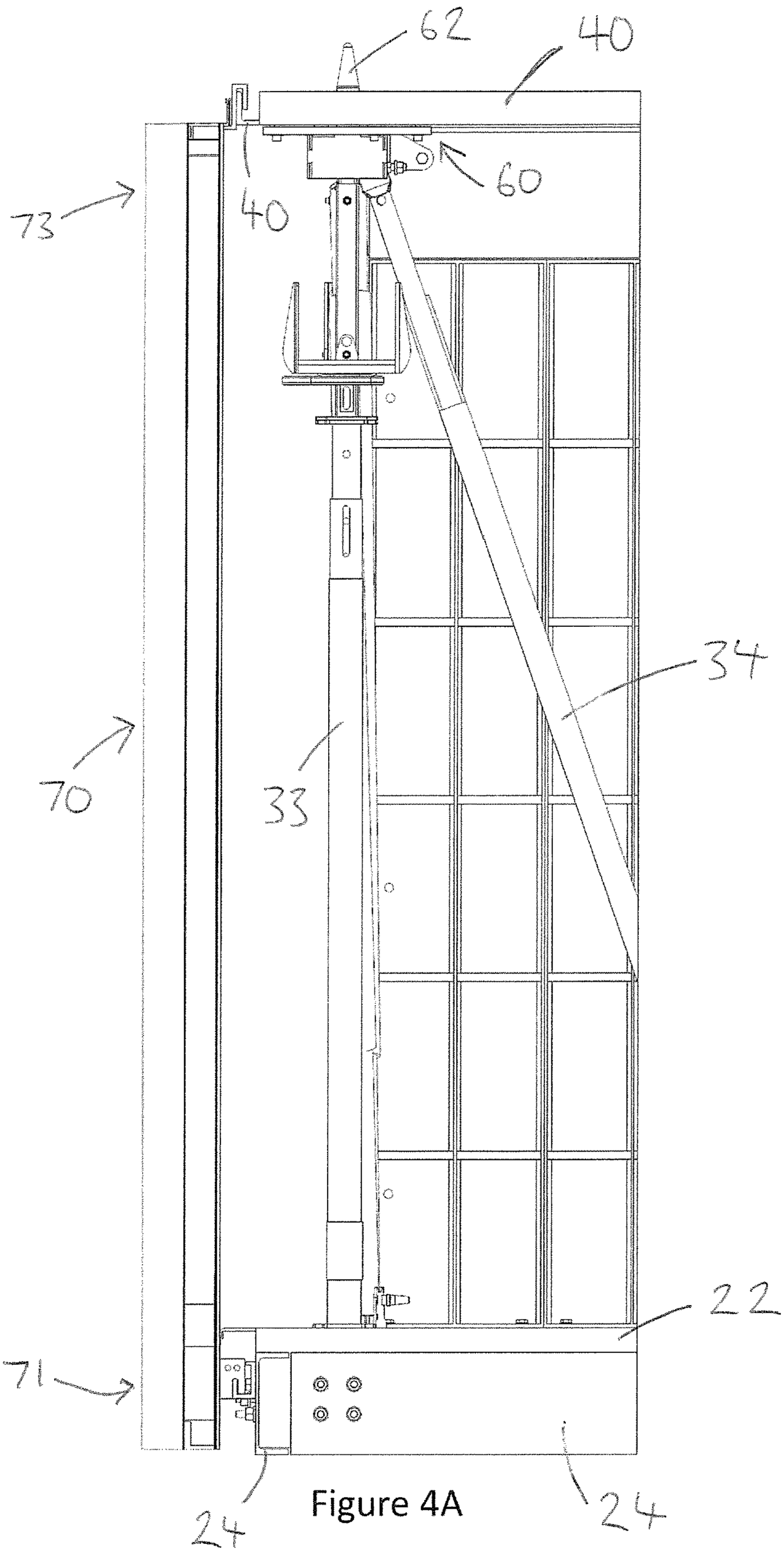

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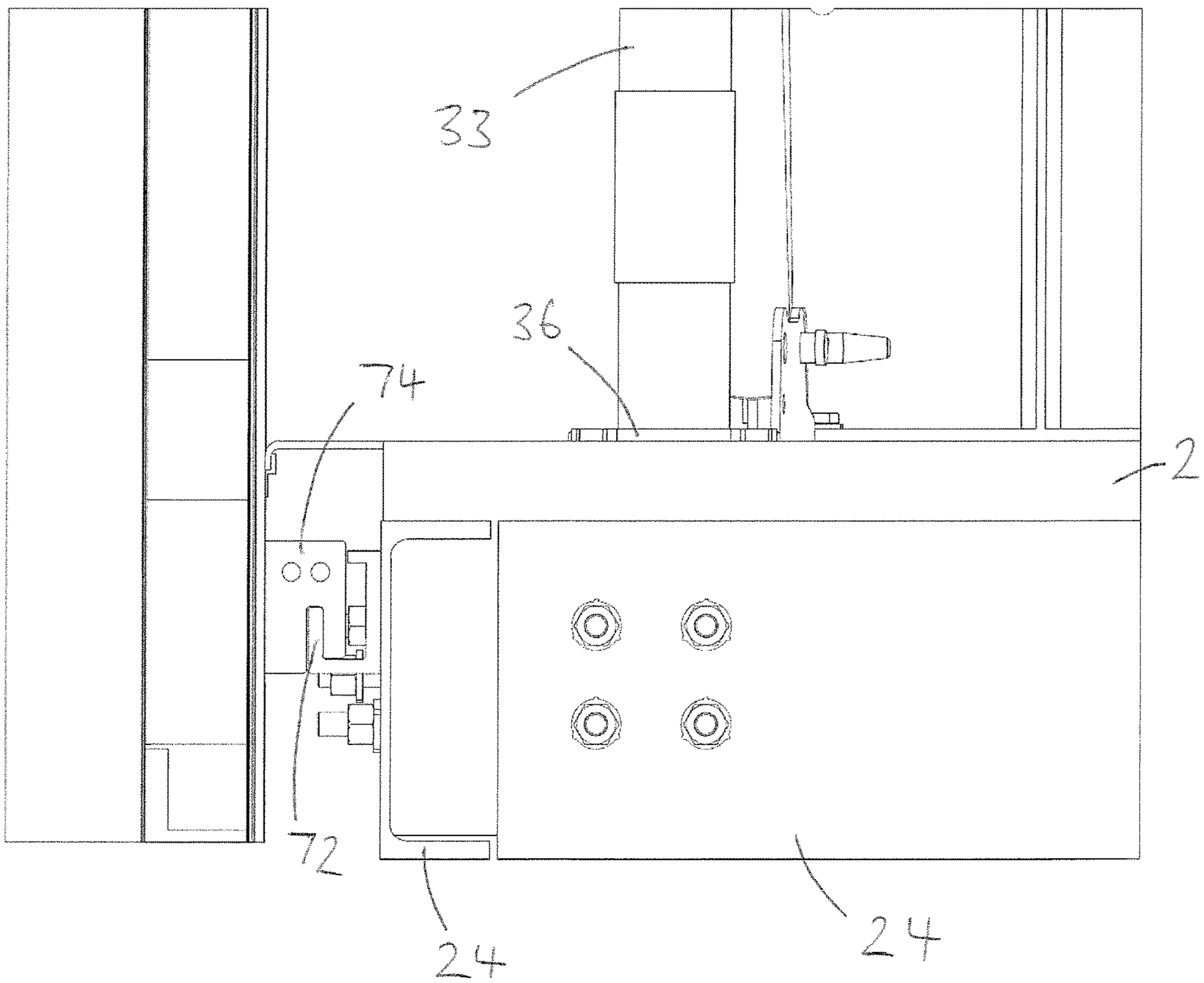

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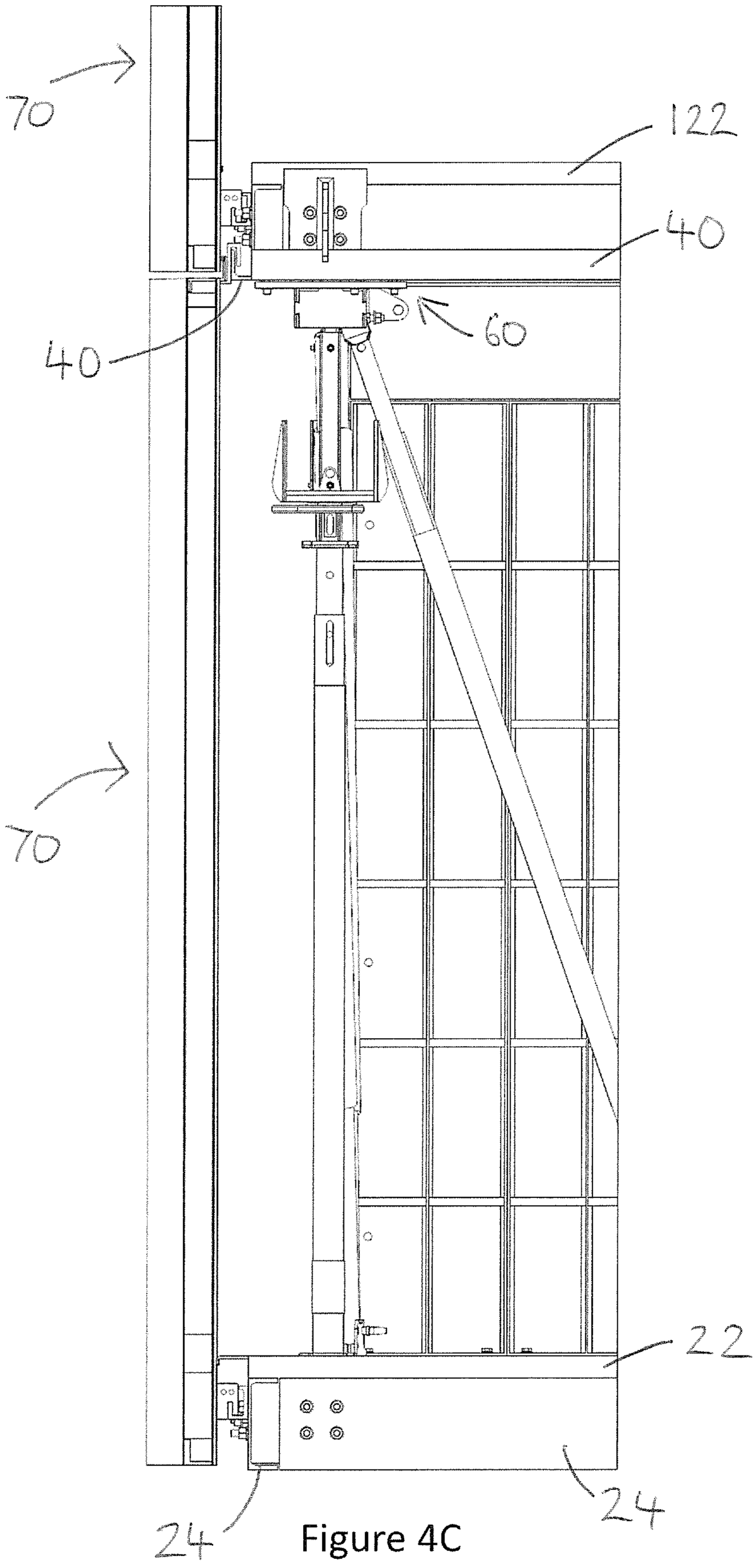

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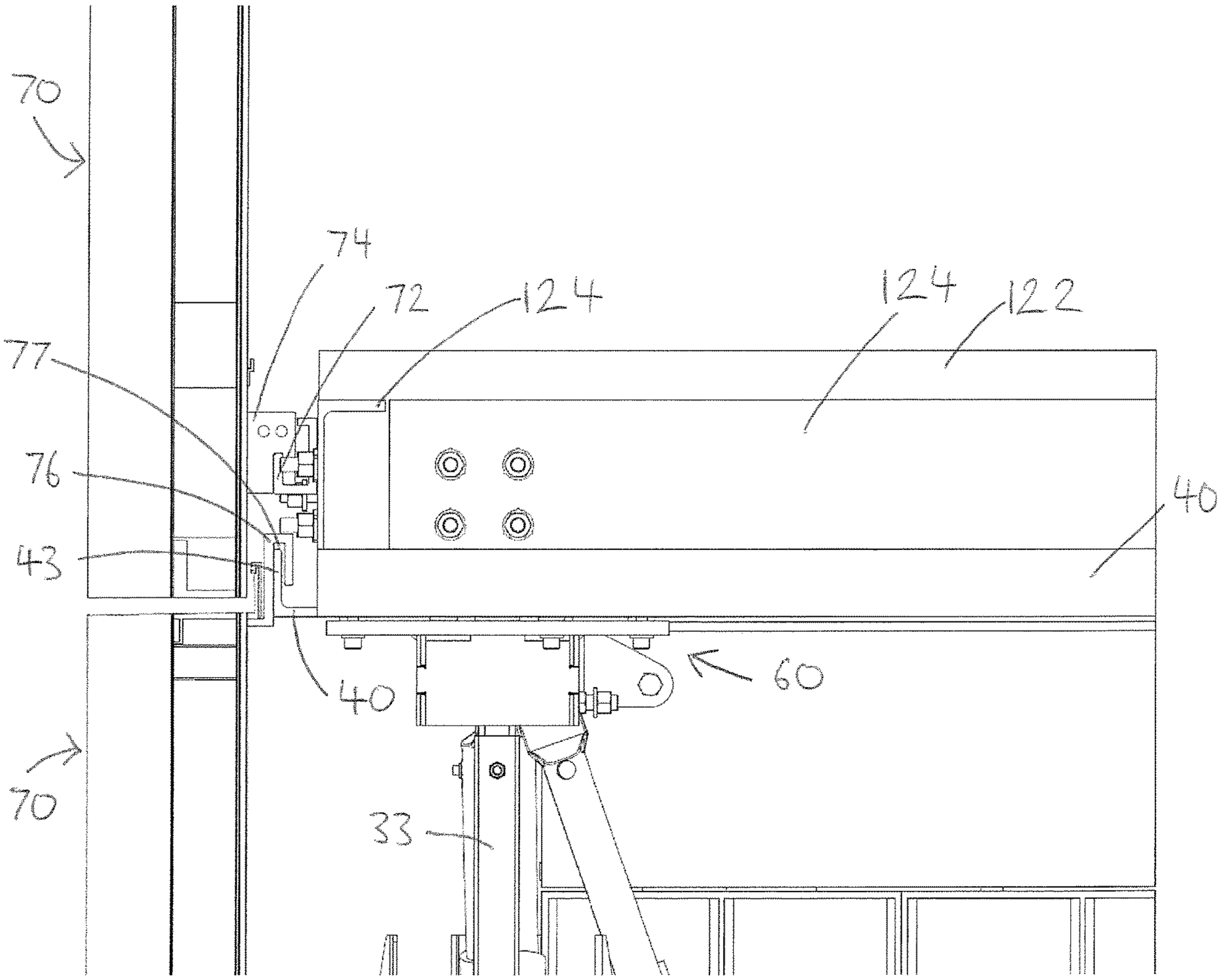


Figure 4D

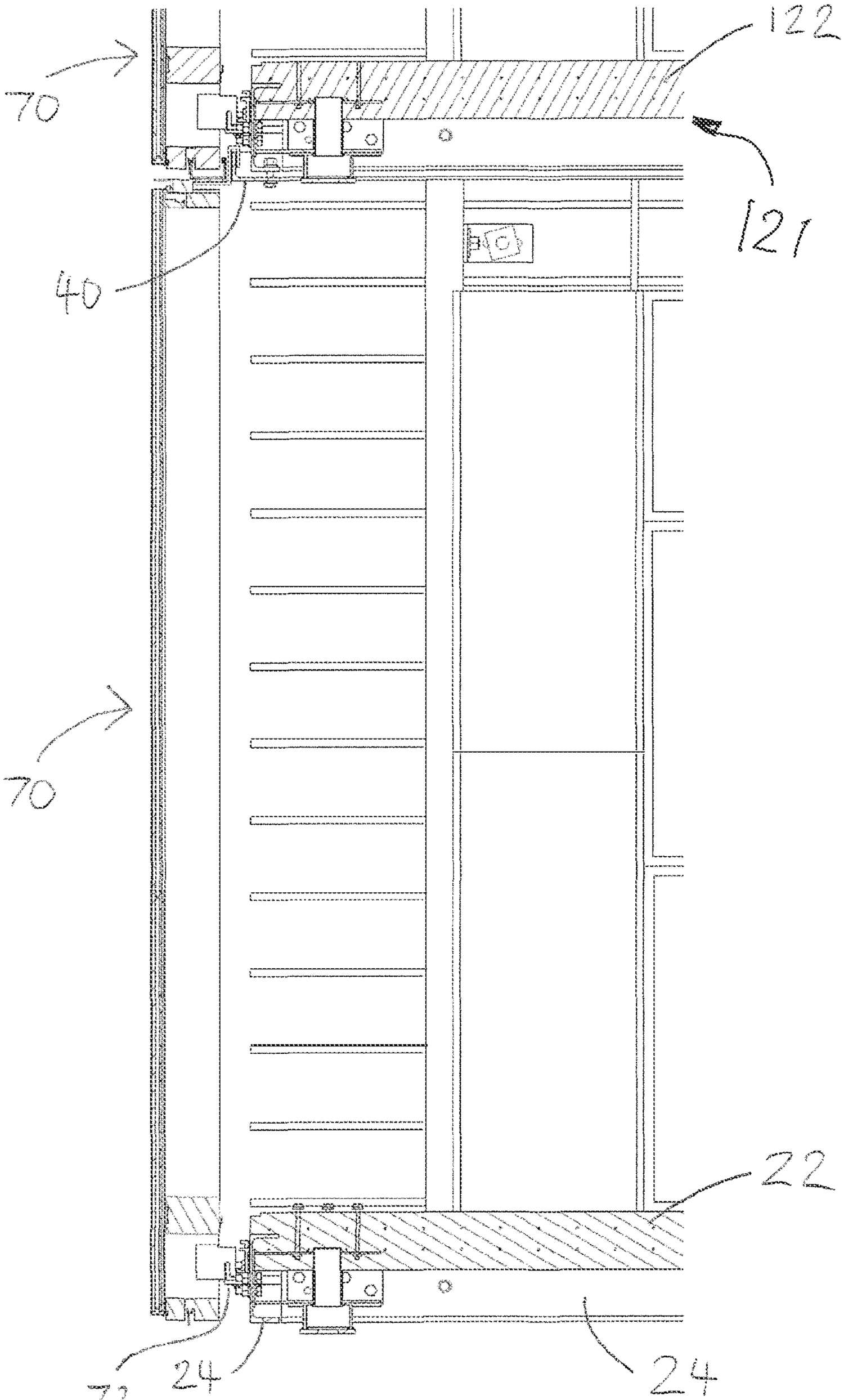


Figure 4E

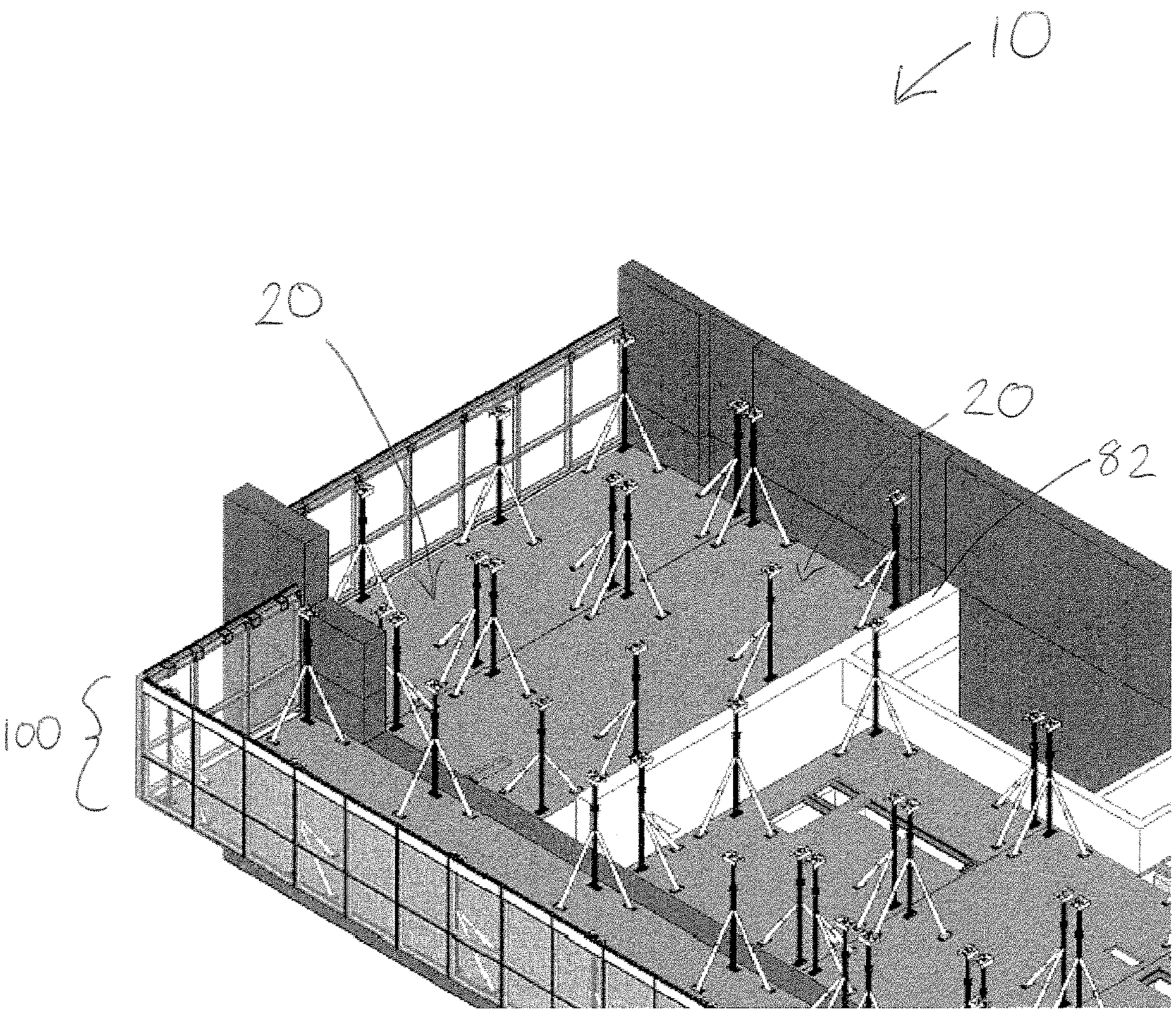
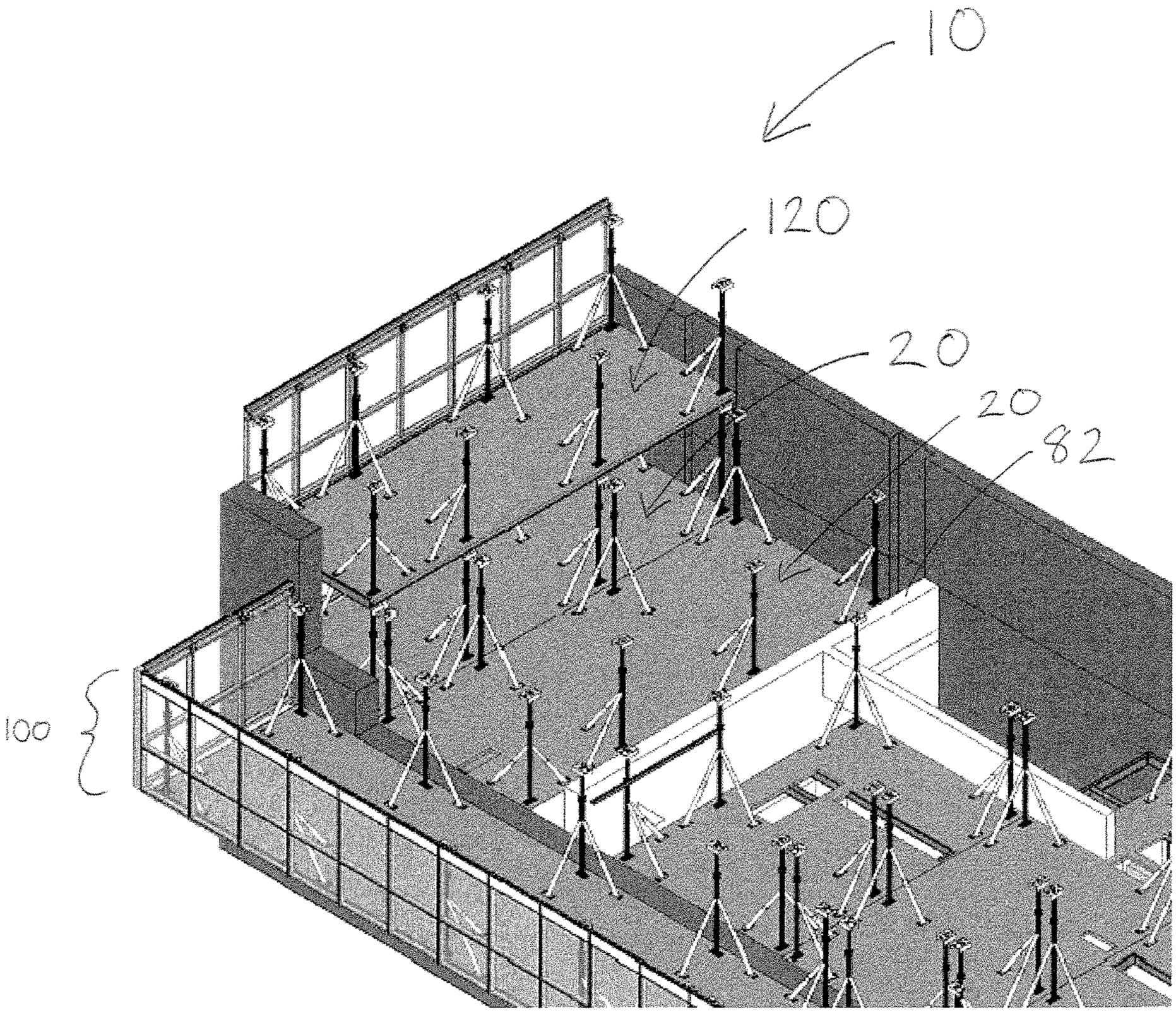


Figure 5A



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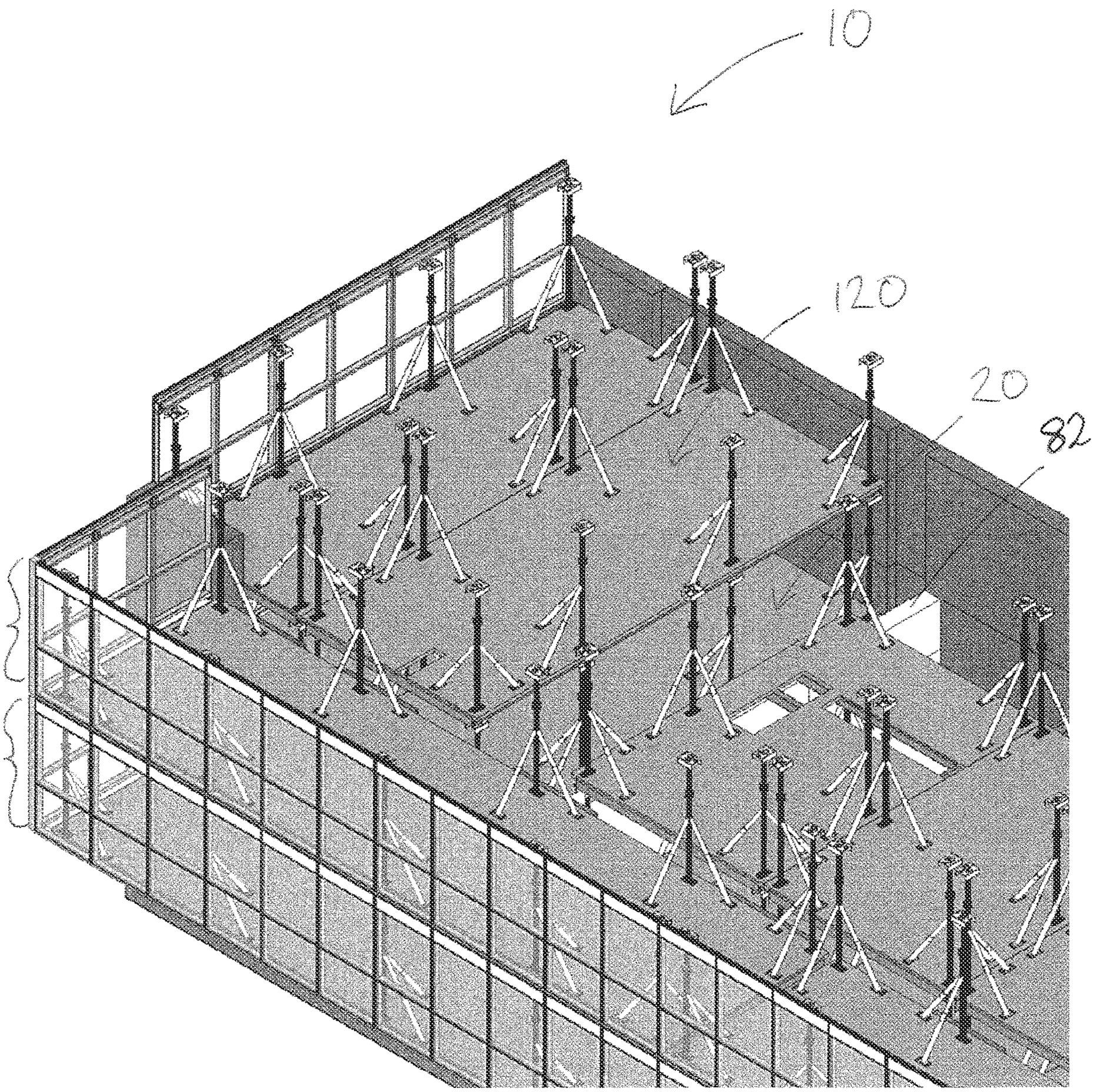

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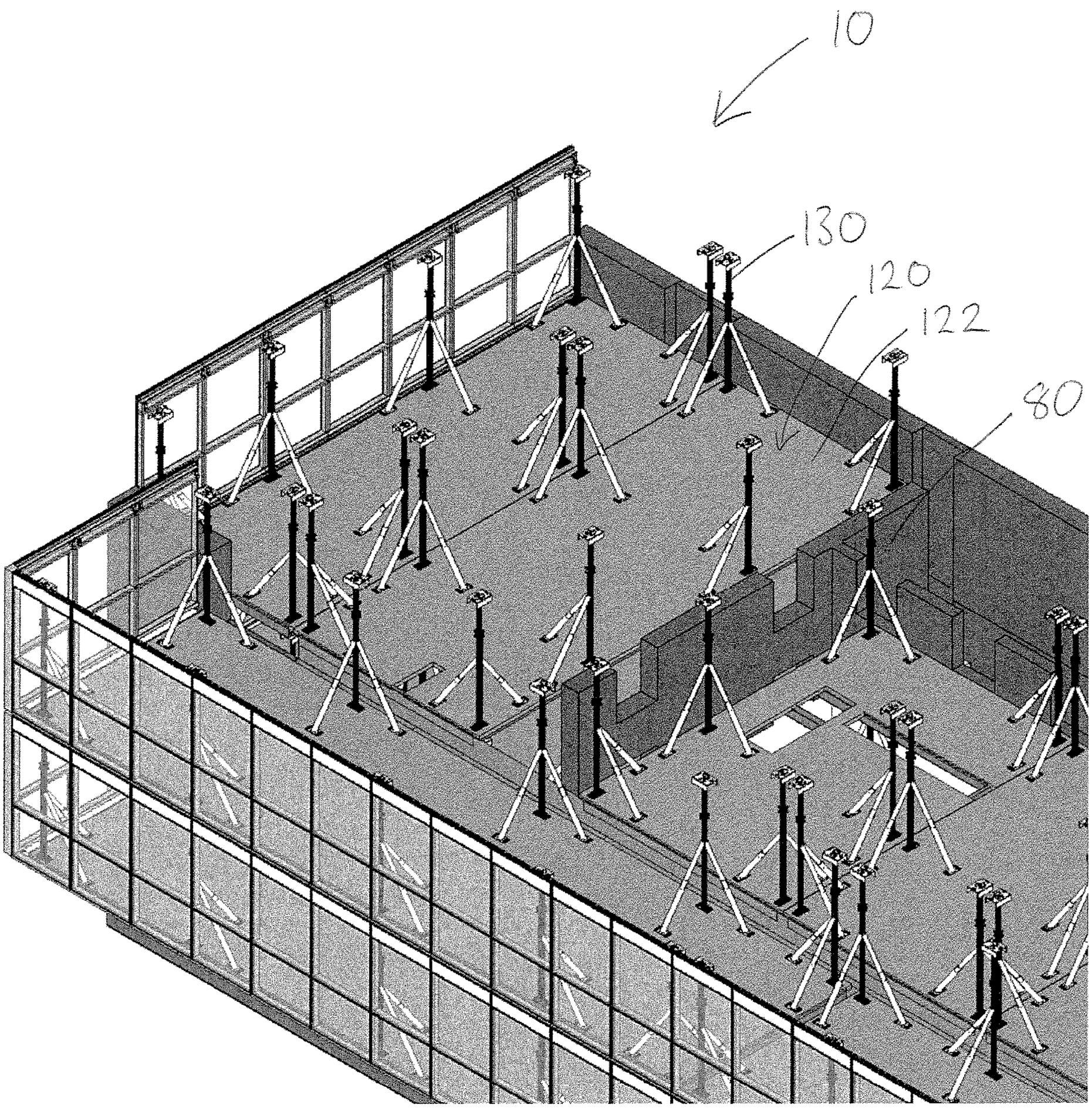


Figure 5D

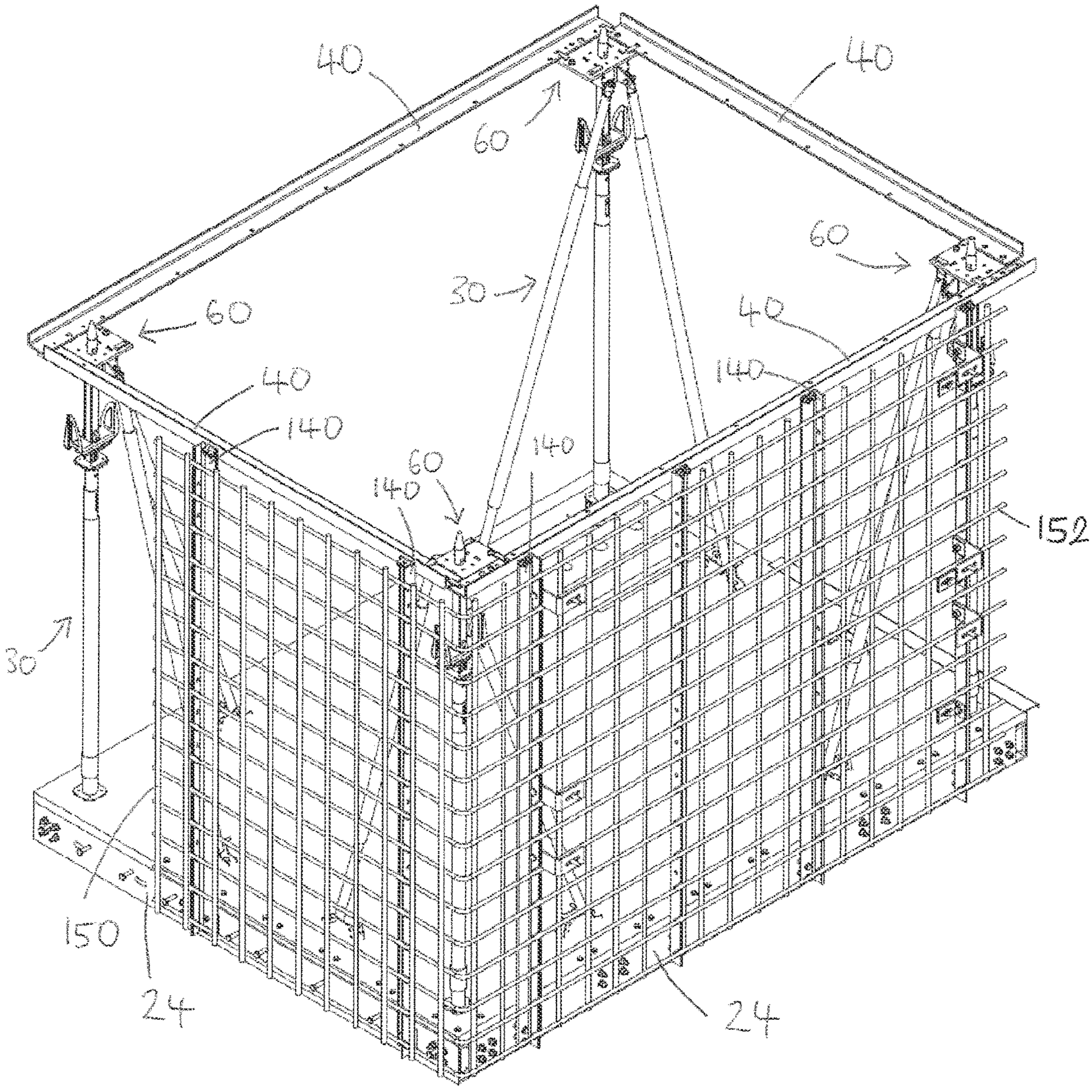


Figure 6A

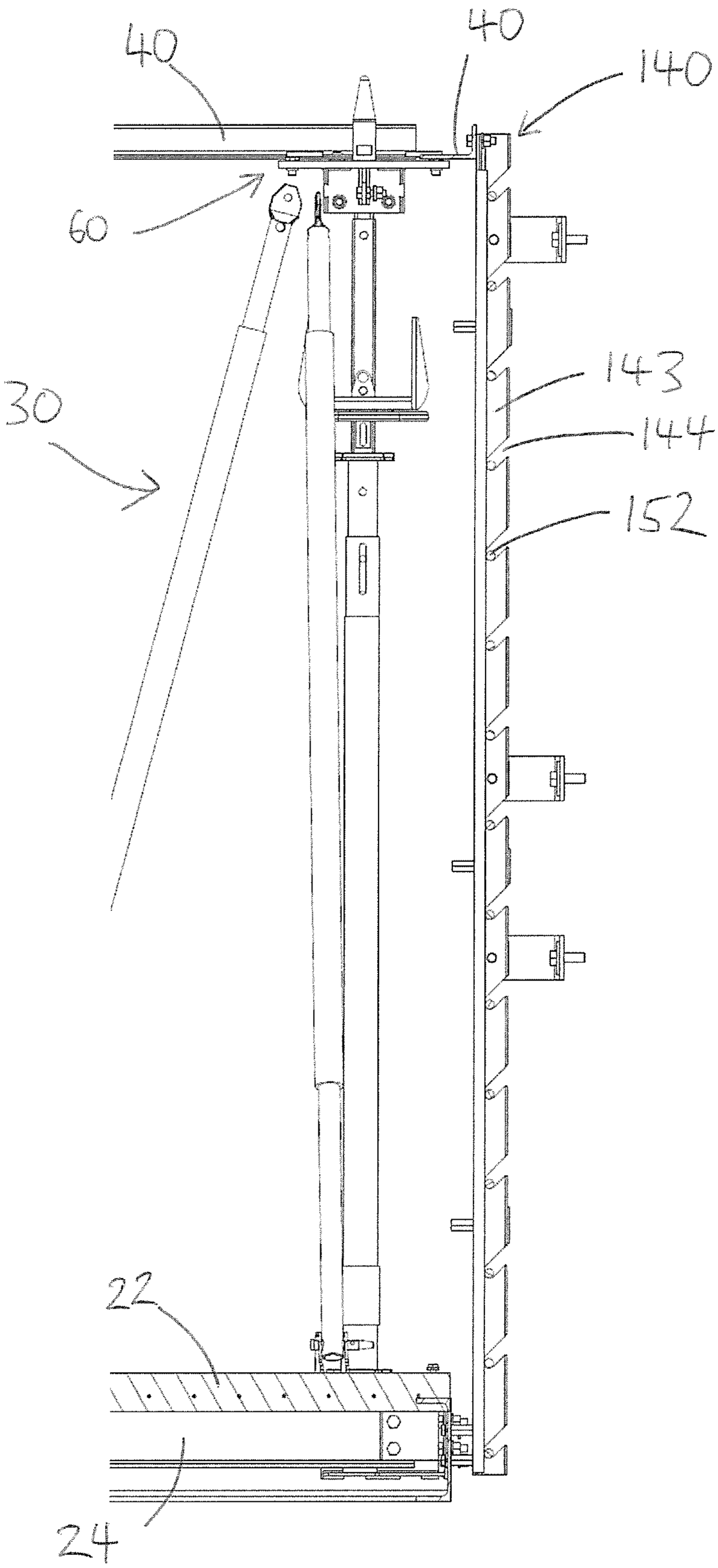
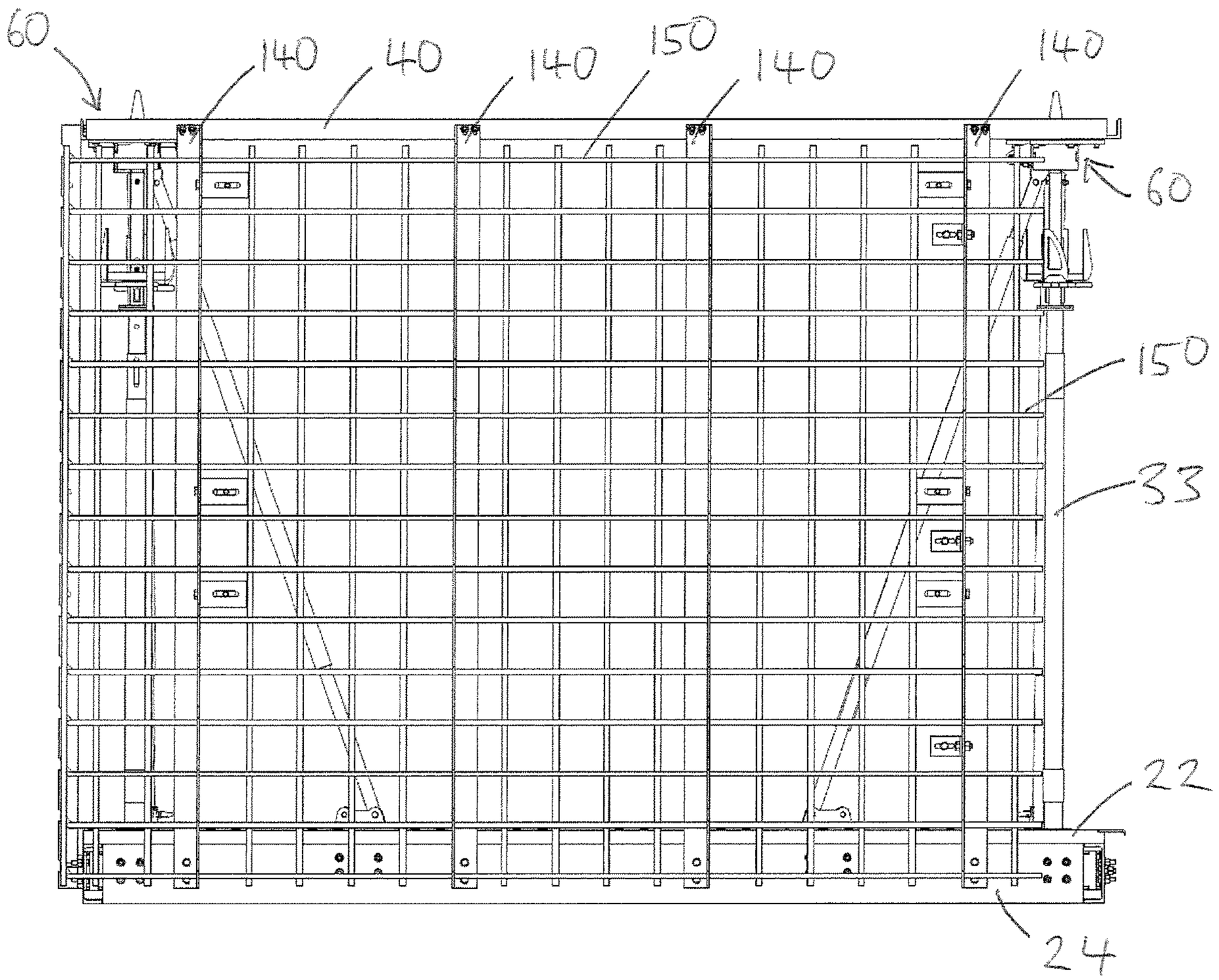


Figure 6B



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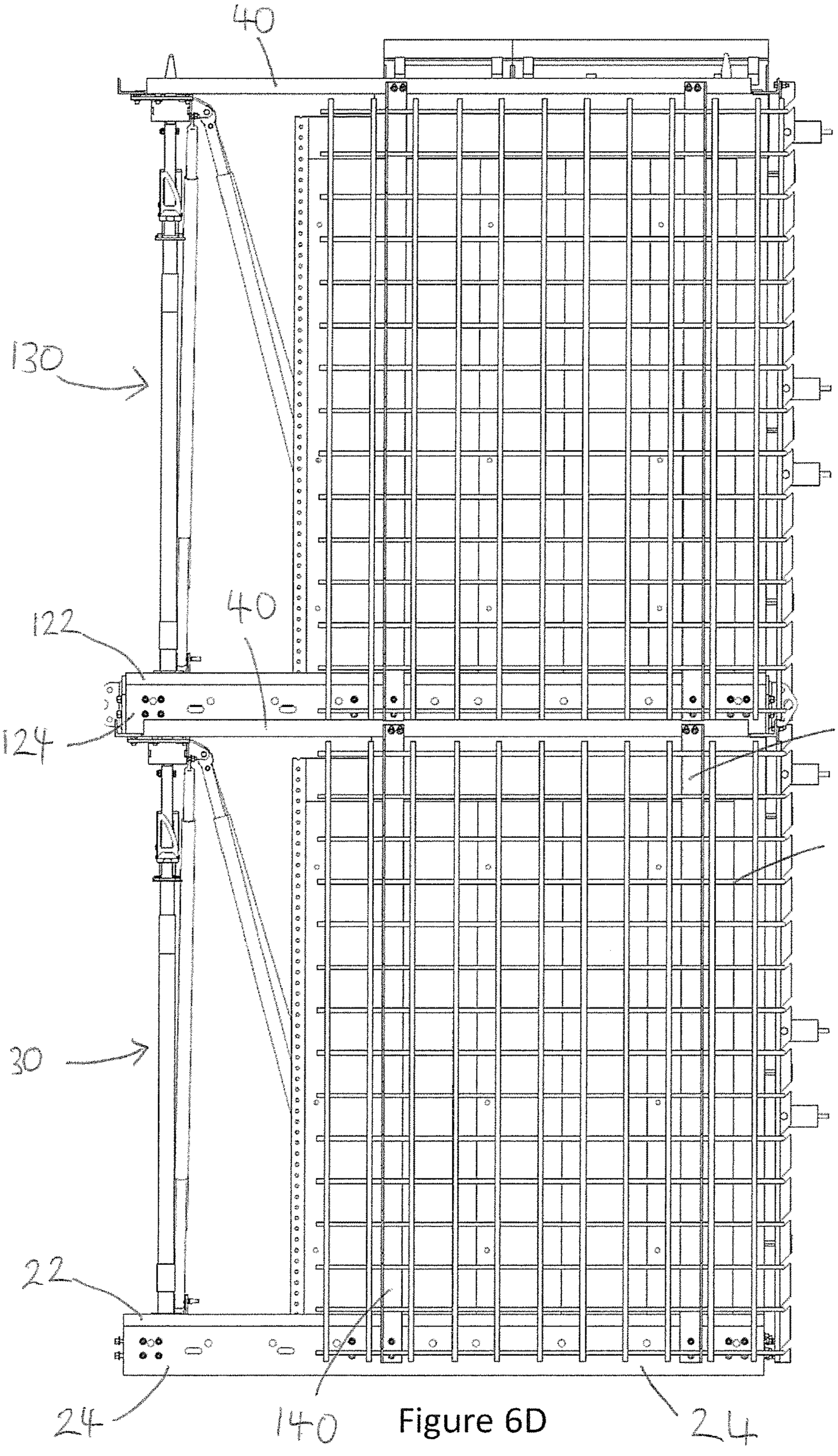

Figure 6D

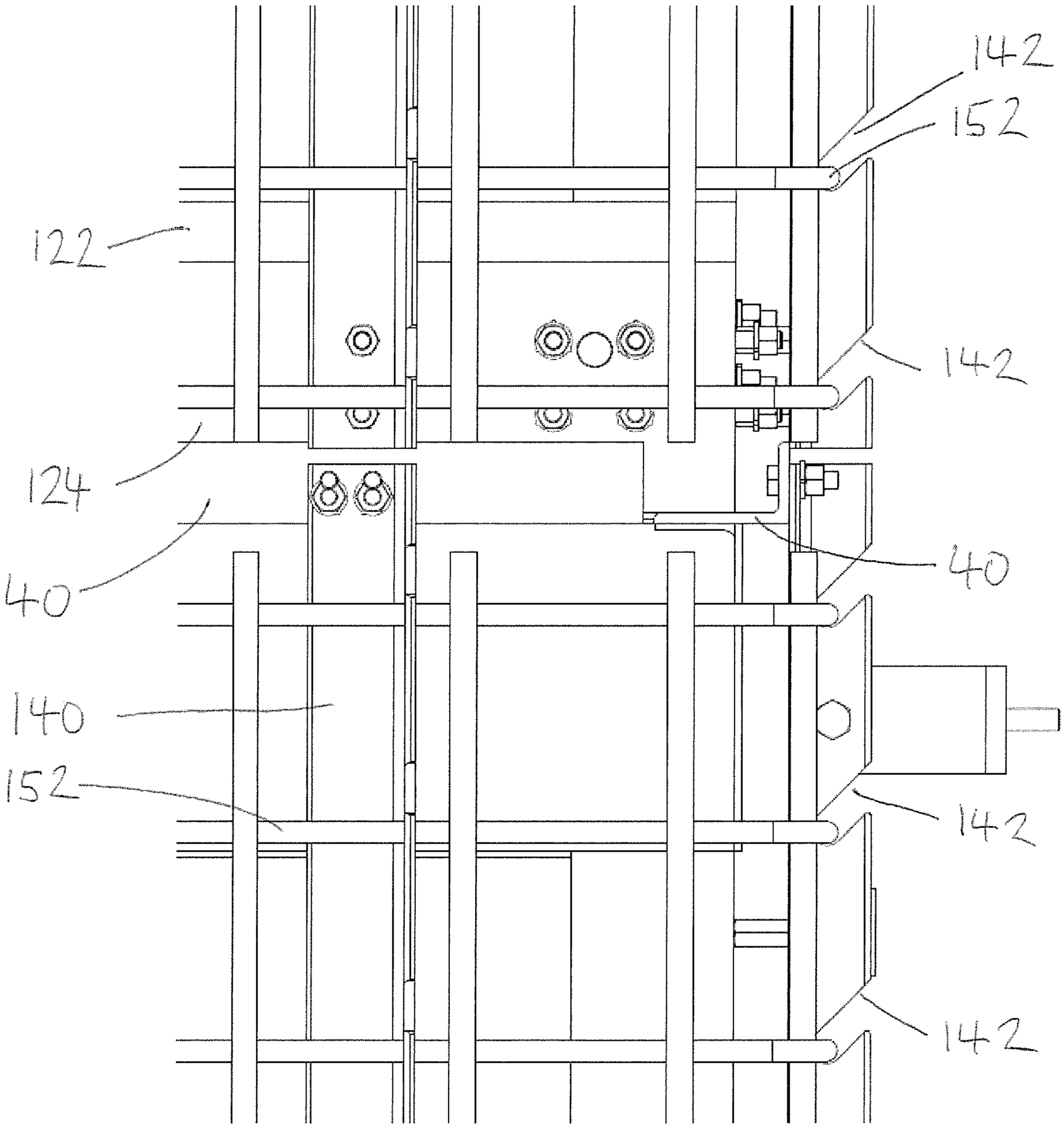

Figure 6E

METHODS AND APPARATUS FOR CONSTRUCTING MULTI-STOREY BUILDINGS

FIELD OF THE INVENTION

The invention relates to methods and apparatus for constructing buildings, in particular buildings constructed using modular units.

BACKGROUND OF THE INVENTION

In the construction industry modular buildings are becoming more popular due to their ability to be constructed on site in shorter timeframes than traditional multi-storey construction. Modular construction involves building and preparing a building module offsite in a factory before transporting and installing the module at an installation location. Despite the time saving benefits of modular construction techniques there is a constant pursuit to improve these methods of construction with the aim of achieving time savings and cost savings in the overall construction of the building.

It is in light of these pursuits for efficiencies in current the construction of modular buildings that the invention was conceived.

SUMMARY OF THE INVENTION

The invention provides a method of constructing a modular multi-storey building including: assembling first and second building modules in a vertical arrangement at an installation location to form a multi-storey building structure, wherein temporary support members between the first and second building modules vertically support at least part of the second building module above the first building module; installing a permanent support structure and connecting it to the first and second building modules to vertically support the second building module above the first building module; and removing the temporary support members.

By providing a method in which the temporary support members can be removed it is possible to salvage and reuse building materials, such as steel supports, that becomes redundant once permanent support structures are installed.

The term building module is intended to refer to a construction unit that is created off site, for example in a factory setting, and is transported on site to be assembled with other building modules to construct a multi-storey building. The building module could include a basic form comprising a base and a frame fixed to the base that forms the 'bones' of walls and a ceiling.

Alternatively, the building module may comprise a unit in an almost finished state including base, walls, ceiling and even fixtures. Further still, the building module may include a construction falling between the basic and the almost finished forms discussed above.

In an embodiment the method includes at least partially constructing the first building module at a first location before assembling the first and second building modules at the installation location. The temporary support members may be attached to the first building module at the first location. A bracket may be attached to one or more of the temporary support members. A wall structure may be attached to the bracket. The bracket may be attached to the second building module.

In an embodiment the permanent support structure is installed after the second building module has been assembled at the installation location.

By providing a method in which the second building module can be installed before the permanent support structure is installed the installation of building modules can be decoupled from the supply of the permanent support structures.

In an embodiment a third building module is assembled above the second building module before the permanent support structure is connected to the first and second building modules. The third building module may be assembled above the second building module using temporary support members.

In an embodiment a concrete slab is cast to form a base of the first building module. In an embodiment a concrete slab is cast to form a base of the second building module. The base of the second building module may be cast to include a steel beam at least partially embedded into the base of the second building module. The steel beam of the base of the second building module may be located on a locator on one or more of the temporary support members.

In an embodiment concrete is poured to connect the first building module to the permanent support member. In an embodiment concrete is poured to connect the second building module to the permanent support member.

In an embodiment a tripod-type temporary support member is attached to the first building module. In an embodiment the temporary support members are re-used.

Also described herein is a method of constructing a modular building including the steps of:

a) constructing first, second and third building modules;
b) mounting temporary support members to each of the first and second building modules;
c) installing the first building module into the modular building;
d) mounting the second building module to one or more of the temporary support members of the first building module so that at least part of the second building module is supported above the first building module;
e) mounting the third building module to one or more of the temporary support members of the second building module so that at least part of the third building module is supported above the second building module;
f) installing a permanent support member to permanently support the second building module above the first building module, and to permanently support the third building module above the second building module; and
g) removing the temporary support members from the first building module after step e).

The invention also provides a formwork assembly comprising: a first bracket having an elongate body, the elongate body having an attaching section to attach the first bracket to a building structure and a supporting section, the supporting section having a supporting means; a second bracket having an attaching section to attach the second bracket to a building structure and a supporting section, the supporting section having a supporting means; and a mesh made from reinforcing steel bar, the mesh being supported by the supporting means of the first bracket and the supporting means of the second bracket.

In an embodiment the supporting means are open ended slots. The open ended slots may be angled downwards. The horizontal sections of the mesh may be located in the open ended slots. The opened ended slots in the first and second

brackets may be spaced apart so that each horizontal section of the mesh has a corresponding slot.

In an embodiment the first and second brackets are attached to a single common building structure. The common building structure may be a building module.

In an embodiment described herein there is a method of constructing a modular building including the steps of:

a) constructing a base of a first building module;

b) mounting a first end of a temporary support member to the base of the first building module;

c) installing the first building module into the modular building;

d) mounting a second building module to a second end of the temporary support member so that at least part of the second building module is supported by the temporary support member;

e) installing a permanent support member between the first building module and the second building module to support the second building module above the first building module; and

f) removing the temporary support member from the first building module.

A bracket can be attached to the second end of the temporary support member, and the second building module can be attached to the temporary support member via the bracket.

An aperture in the bracket can be aligned with a bracket locator on the temporary support member when attaching a bracket to the second end of the temporary support member.

The base of the first building module can be constructed at a first location, and then transported from the first location to an installation location, where the building module is installed. The temporary support member can be attached to the base of the first building module before the first building module is transported to the installation location.

A wall panel can be attached to the first building module. Preferably the wall panel is attached to the base and the bracket. The wall panel can be attached before the first building module is transported to an installation location.

A height of the temporary support member can be adjusted to a desired height after the temporary support member has been attached to the base of the first building module.

The temporary support member can be detached from the bracket when removing the temporary support structure.

A mesh locator bracket can be installed to the first building module. A prefabricated concrete panel can be installed to connect the first building module to the second building module. Concrete can be poured at the installation location to connect the prefabricated concrete panel to connect the first and second building modules.

The second building module can be installed directly above the first building module. The temporary support members can be reused.

In an embodiment described herein there is a method of constructing a modular building including the steps of:

a) constructing a base of a first building module;

b) attaching a support member to the base of the first building module;

c) installing the first building module;

d) installing a second building module so that at least part of the second building module is supported by the support member;

e) installing, after step d), a prefabricated panel between the first building module and the second building module to support the second building module.

By providing a method in which a second building module is installed before a prefabricated panel is installed to support the second building module the installation of building modules can be decoupled from the supply of walls and other permanent support structures.

The first building module can be part of a first level of the modular building and the second building module is part of a second level of the modular building, and wherein all of the building modules for the first and the second levels are installed before step e) is performed. The base of the first building module can be constructed at a first location, and then transported from the first location to an installation location, where the building module is installed.

Before step e) is performed a third building module can be installed at the installation location so that at least part of the third building module is supported by a second support member, the second support member being attached to the second building module so that at least part of the third building module is supported by the second support member.

Step e) can include pouring concrete at the installation location to connect the prefabricated panel to the first building module. Preferably the prefabricated panel is a prefabricated concrete panel. Step e) can include lowering the prefabricated panel into position between the first building module and the second building module by crane.

The support member can be a temporary support member. The temporary support member can be a temporary support member as described above.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment, incorporating all aspects of the invention, will now be described by way of example only with reference to the accompanying drawings in which;

FIG. **1**A is an isometric view of a temporary support member in accordance with an embodiment of the invention;

FIG. **1**B is an isometric view of a locator plate attached to the temporary support member shown in FIG. **1**A;

FIG. **1**C is a top view of the temporary support member shown in FIG. **1**A;

FIG. **1**D is a side view of an upper end of the temporary support member in FIG. **1**A;

FIG. **1**E is an isometric an isometric view of an alternative temporary support member in accordance with an embodiment of the invention;

FIG. **1**F is an isometric view of a locator plate attached to the temporary support member shown in FIG. **1**E;

FIGS. **1**G and **1**H are top and side views of the temporary support member shown in FIG. **1**E;

FIG. **2**A is an isometric view of a bracket attached to the temporary support member shown in FIG. **1**A;

FIG. **2**B is a top view of the temporary support member and bracket shown in FIG. **2**A;

FIG. **2**C is a side view of the temporary support member and bracket shown in FIG. **2**A;

FIG. **3**A is an isometric view of a first building module in accordance with an embodiment of the invention;

FIG. **3**B is a top view of the first building module shown in FIG. **3**A with a bracket attached to the temporary support members;

FIG. **3**C is an isometric view of the first building module shown in FIG. **3**B;

FIG. **4**A is a side view of a first building module with a temporary support member and a wall panel (without a building module installed above the first building module);

FIG. **4**B is a close up side view of connection between the first temporary support member and the first building module shown in FIG. **4**A;

FIG. **4**C is a side view of the building module shown in FIG. **4**A with a second building module installed above the first building module;

FIG. **4**D is a close up side view of the connection between the second building module and the temporary support member shown in FIG. **4**C;

FIG. **4**E is a side view of a building module, similar to that shown in FIG. **4**C, with the temporary support member removed;

FIG. **5**A is an isometric view of a partially constructed modular building with a first building module installed;

FIG. **5**B is an isometric view of the partially constructed modular building shown in FIG. **5**A with a second building module installed;

FIG. **5**C is an isometric view of a partially constructed modular building with all of the building modules of a first and second levels installed;

FIG. **5**D is an isometric view of the partially constructed modular building in FIG. **5**C with a prefabricated panel installed;

FIG. **6**A is an isometric view of a building module with a rebar bracket and a rebar mesh attached to the bracket shown in FIG. **2**A and the temporary support member shown in FIG. **1**A;

FIG. **6**B is a side view of the building module shown in FIG. **6**A;

FIG. **6**C is a top view of the building module shown in FIG. **6**A;

FIG. **6**D is a front view of two levels of a modular building having rebar brackets and a rebar mesh attached to brackets shown in FIG. **2**A and temporary support members shown in FIG. **1**A; and

FIG. **6**E is a close up side view of the connection between the rebar bracket and the bracket shown in FIG. **2**A.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

FIGS. **1**A to **5**D illustrate a method of constructing a modular building **10**. The modular building is typically a multi-storey building made of building modules formed off site. The transportation of each module from a first location off site to the installation site and the subsequent construction requires the modules to maintain a certain stability so that they can be handled by cranes and other handling equipment on and off the transportation vehicle, and placed or stacked on site so that they can support other modules placed on top. Such stability requires a base, preferably a cast concrete slab, and support columns placed at strategic locations on the base to be able to support another module placed on top.

The inventor has realised that once the building modules have been installed on site and concrete structure (walls and columns) have been created or erected, the columns traditionally mounted on the base in the factory and that form a permanent part of the finished building, which columns are often formed of steel, can in fact become redundant as the building can be engineered to make the columns non-load bearing. The load in such a building is instead taken by the concrete structure, not the steel columns. The concrete structure can include concrete cores (for lift and stair wells) and shear walls (internal and external).

Accordingly, the method described herein is directed to a technique of providing structural integrity to a building module when required, without sacrificing or wasting structural components, which can be expensive.

In its basic form the method involves assembling building modules in a horizontal and/or vertical arrangement to form a building structure, wherein the modules include temporary supports, such as columns, to be able to support the modules on the next level above or a roof structure above. In describing the temporary support of modules, it is understood that the temporary supports also support the formwork used to install the permanent support structures. This could include the creation of concrete components used to connect and stitch together the modules. Once the modules are in place permanent support members are installed to connect between the lower module and the upper module (or roof) and the temporary support columns are removed (and can be re-used). Permanent supports can include the installation of pre-fabricated load bearing panels, such as concrete panels, or the in situ creation of concrete walls, including core and shear walls, through pouring or spraying ('shotcreting') wet concrete and allowing it to dry. Alternatively, the permanent support members could be steel braced walls, or any other suitable permanent structure.

The temporary support members could include the provision and changeover of more than one type of support structure. For example, if the building module is installed on site comprising a pre-formed base with upstanding steel columns attached thereto, after a second module is placed on top and held spaced above via the steel columns, a removable temporary support (such as the tripod-type discussed further below) for supporting the structure during construction (eg. concrete application) could be positioned between the first and second modules to support the upper module and to support formwork used (in a sacrificial or temporary way) in the in-situ forming of concrete elements including columns, panels or beams. The in-situ concrete elements could form part of the exterior façade of the building, or could form part of a concrete core, or could be the elements laterally and vertically connecting together the building modules.

Once the temporary supports are in place, the steel columns, which served to support the building module during transportation to site and erection, may then be removed (for re-use). The permanent structure is then installed by placement/pouring/spraying, and once the permanent structure, including concrete elements, is set and capable of bearing the load of the upper module, the temporary supports can be removed (and re-used).

Alternatively, it may be suitable to do away with steel columns altogether and instead use only one kind of removable temporary purpose-built support during construction of the multiple levels and installation of the permanent supports. A further alternative could be to employ a combination of temporary steel columns as well as the further temporary purpose-built supports.

Broadly, and referring to FIGS. **3**A to **5**D, the method includes the following steps:

a) constructing a base **21** of a first building module **20**;

b) attaching a first end of a temporary support member, shown as first end **31** of tripod **30**, to the base **21** of the first building module **20**;

c) installing the first building module **20** on site;

d) attaching a second building module **120**, including formwork, to a second end **32** of the tripod **30** so that at least part of the second building module **120** is supported by the tripod **30**;

e) installing a permanent support member, such as prefabricated concrete wall **80** or creating a concrete

element by applying concrete to formwork, between the first building module **20** and the second building module **120** to support the second building module **120**; and

f) removing the tripod **30**.

It will be appreciated that the temporary support member in the form of a tripod **30** in the described embodiment, acts to space the second building module from the first building module during construction. In this way the second building module, and formwork between the modules, is located in the correct position by the temporary support member until the permanent support member(s) is installed or applied on site. It is the permanent support members that provide the structural integrity to the building. Thereafter the temporary support member may be removed.

It is envisaged that the base **21** of the first building module **20** could be constructed at a first location, and then moved, for example by being transported from the first location to an installation location, where the building module is installed. The first location may be a factory or a warehouse where the initial components of the first building module may be more easily assembled in an assembly line fashion, in order to assist in shortening overall construction time on site at the installation location. It is envisaged that the tripod **30** could be attached to the first building module **20** either before or after the first building module **20** is transported from the first location to an installation location.

Alternatively, if there is room on the building site, an assembly area may be allocated, for example, in an area that is designated as a courtyard or garden in the finished building. In this example the first building module **20** can be constructed on the building site in a designated assembly area before being moved into position, for example by a crane, and installed. Again, is envisaged that the tripod **30** could be attached to the first building module **20** either before or after the first building module **20** is positioned in an installation location. It will be understood that locating the assembly area, or factory, on the building site will help reduce transportation costs.

Referring to FIGS. **2**A to **3**C, the method may include the step of attaching a bracket, shown as angle bracket **40**, to the second end **32** of the tripod **30**. The angle bracket **40** can then act as an interface or formwork between the tripod **30** and other building components, such as the second building module **120** or a wall structure. It is envisaged that the wall structure could be an internal wall, a façade wall, or a structure to allow creation of a wall (such as shutters for pouring or spraying concrete walls, or a rebar bracket **140** as described later). If the angle bracket is used then the second building module may be attached to the tripod **30** via angle bracket **40**.

FIGS. **1**A to **1**D illustrate a first embodiment of the tripod **30**. The tripod **30** has a main shaft **33** and two auxiliary legs **34**, **35** that stabilise the main shaft **33**. The main shaft **33** and the two auxiliary legs **34**, **35** each have a foot **36** that enables the tripod **30** to be attached to the upper surface or floor **22** of the building module **20**. The feet **36**, which are at the first end **31** of the tripod **30**, have one or more apertures **37** that allow fasteners to be inserted through the feet **36** to fasten and secure the first end **31** of the tripod **30** to the floor **22** of the building module **20**. The main shaft **33** is telescopic to allow the height of the tripod **30** to be adjusted as desired

The main shaft **33** extends from the first end **31** of the tripod **30** to the second end **32** of the tripod **30**. The main shaft **33** is substantially straight along its entire length so that in use the main shaft **33** is substantially vertical when attached to a building module so that it can support a load, usually of at least one storey above, if not more. The two auxiliary legs **34**, **35** are spaced 90 degrees from each other about the axial direction of the main shaft **33**. In other words, the auxiliary legs **34**, **35** lie in orthogonal planes.

A locator plate **60** is attached at the top of the main shaft **33**. The locator plate **60** is attached to the top by fasteners, such as bolts, but it could be welded thereto. The locator plate **60** is used to assist in aligning a second building module **120** above the first building module **20**. The locator plate **60** has a locator, shown as a protrusion, and more specifically shown as locator pin **62** that extends away from the face of the locator plate **60**. The tip **63** of the locator pin **62** convergingly tapers as it extends away from the locator plate **60**. In other words, the tip **63** of the locator pin **62** narrows as it extends away from the location plate **60**. The locator pin **60** has a cylindrical base **64** that is wider than the tip **63** of the pin **62**. The narrower tapered end of the locating pin **62** makes initial positioning of the second building module **120**, while the wider base of the locating pin **62** ensures accurate alignment of the second building module **120** on top of the locator plate **60**.

FIGS. **1**E to **1**H illustrate a second embodiment of the tripod **230**, with a second embodiment of the locator plate **260**, which is attached to the tripod by bolts **269**. Clamp nuts **268** serve to secure the angle bracket **40** to the locator plate **260**, as discussed below in respect of the embodiment of FIGS. **2**A to **2**C. The tripod **230** has a main shaft **233** and two auxiliary legs **234**, **235** that stabilise the main shaft **233**. The main shaft **233** extends from the first end **231** of the tripod **230** to the second end **232** of the tripod **230**. Feet **236** are located at the first end **231** of the tripod **230**. The locator plate **260** has a locator, shown as a protrusion, and more specifically shown as location block **262** that is elongate in shape and extends away from the face of the locator plate **260**. The location block **262** convergingly tapers as it extends away from the locator plate **260**. In other words, the location block narrows as it extends away from the location plate **260**. The location block is wider than it is thick, to assist in precise alignment.

FIGS. **2**A to **2**C illustrate the angle bracket **40** attached to the tripod **30**. Bracket locators, shown as bolts **61**, are used to locate the angle bracket **40** on the locator plate **60**. The bolts **61** allow the angle bracket **40** to be quickly and easily located on top of the locating plate **60**. The locator plate **60** also has clamp nuts **68** that secure the angle bracket **40** to the locating plate **60**. The angle bracket **40** is L-shaped, having a primary section **41** and a secondary section **43**. The angle bracket **40** can be a prefabricated channel (PFC). The primary section **41** is substantially perpendicular to the secondary section **43**. The L-shaped configuration of the angle bracket **40** allows building components to be attached to the angle bracket **40** at different angles. For example, the base **121** of a second building module could be attached to the primary section **41** of the angle bracket **40**, and a wall, perpendicular to the base **121** of the second building module **120**, could be attached to the secondary section **43**.

The method described above may therefore include attaching an angle bracket **40** to the second end **31** of the tripod **30** by aligning a locating aperture **42** in the angle bracket **40** with a bracket locator, such as bolt **61**, on the locating plate **60**.

FIGS. **3**A to **3**C illustrate a first building module **20** having a concrete floor **22**. The first building module **20** may also have steel beams **24**, or prefabricated channel, cast in around its perimeter or part thereof, which adds rigidity to the concrete floor **22** but which can also double up to act as an angle bracket **40** to which the tripods are attached at an

upper end. Tripods **30** are attached to the upper side **23** of the concrete floor **22**. The tripods **30** are secured to the concrete floor **22** by bolts that are fastened through apertures **37** in the feet **36** of the tripod **30**. The tripods **30** will support a building module above the first building module during construction of the modular building. The number of tripods **30** required will therefore depend on the characteristics of the building, with the requirement that there must be sufficient tripods to support the building module above the tripod **30** before and during concrete application, and the subsequent drying of the concrete. Referring to FIGS. **3**B and **3**C, an angle bracket **40** is installed on the tripods **30** that extends across multiple tripods **30**.

While the tripod spacing depends on the building characteristics, it is envisaged that the spacing between tripods could be less than 8 meters. Alternatively, the spacing between tripods could be less than 6 meters, or between 1 and 3 meters. The spacing is also dependent on the additional structures that the tripods will need to support. For example, if the tripods will also support a façade wall the spacing may be less than if the supports only need to support a second building module above the tripod.

While the angle bracket **40** was discussed as extending across multiple tripods **30**, it is envisaged that there could instead be multiple angle brackets **40** with one attached to each tripod **30**.

Referring to FIGS. **3**A to **5**D, an example of constructing two modules of a modular building will now be described in detail. The process begins in a warehouse, where steel beams **24** are positioned on a construction bed/table. Concrete is then poured to form a slab that forms a concrete floor **22**. The concrete floor **22** also embeds the steel beams **24** (or prefabricated channel— PFC), which add rigidity to the concrete floor **22** and protects the edges.

It is, however, understood that the slab may be created without a perimeter prefabricated channel steel beams. As shown in FIG. **4**A, the steel beams **24** are partially embedded in the concrete floor **22**. As shown in FIG. **3**A, the steel beams **24** are located at the external perimeter of the concrete floor **22**. The concrete floor and the steel beams form a base **21** of a building module.

Once the concrete slab has set the base **21** is removed from the construction bed/table and one or more tripods **30** are placed in position on the upper side **23** of the concrete floor **22** (as shown in FIG. **3**A). Bolts are used to attach the tripods **30** to the upper side **23** of the concrete floor **22**. The bolts are inserted through apertures **37** in the feet **36** of the tripod **30** and are screwed into the concrete floor **22**. The height of the tripod **30** is then adjusted to the desired height. Each of the tripods are adjusted to the same height.

Once the height of all of the tripods **30** has been set the angle bracket **40** is located on the locator plates **60** of the tripods **30**, which are at the second end **32** of the tripod **30**. Once the angle bracket **40** is in position the angle bracket **40** is secured to the tripod **30** by the clamp nuts **68**.

A wall structure, such as a wall panel, and shown as façade wall **70**, can be attached to the building module **20** at this stage. To attach the façade wall **70** a façade bracket **72** is fixed to the steel beam **24** of the module base **21**, for example by bolts or rivets. A façade wall bracket **74** is attached to a lower end **71** of the façade wall **70** to allow connection to the façade bracket **72**. The façade wall **70** has alignment means, shown as alignment bracket **76**, located at the upper end **73** of the façade wall **70**. The alignment bracket **76** has a channel **77**. The façade wall **70** can be lowered into position so that the façade wall bracket **74** contacts and rests on the façade wall bracket **72**, and so that the secondary section **43** of the angle bracket **40** is located in the channel **77** of the alignment bracket **76**.

It is envisaged that the tripods **30** and the wall structure(s) or wall panel(s) could be attached to the module/base either before or after the first building module is transported to the installation location.

By installing the angle bracket **40** and outer walls to the building module **20** before the module is moved into the installation position the building site can operate with increased safety. This is because the installation of the outer walls removes the live edge of the building site, thereby eliminating a live edge for workers to fall from. In addition, by removing the live edge the construction process also becomes more efficient as there is no need for external barriers to be installed around the building before workers can enter the worksite.

After the angle bracket(s) **40** have been installed on the tripods **30** the first building module **20** is transported from the warehouse to an installation location, such as a building site. The first building module **20** is then installed at the building site (either on the ground floor or above another building module already installed).

FIG. **5**A illustrates a partially constructed modular building in which the first building module **20** has been installed. Referring to FIG. **5**B, a second building module **120**, which may or may not be similar or identical to the first building module **20**, is attached to the primary section **41** of the angle bracket **40** of the first building module **20**. In this way at least part of the second building module **120** is installed above, and supported by, the tripod **30**, and thereby supported by the first building module **20**. The second building module **120** is aligned using the locator pins **62** on the locator plates **60**, which are attached to the tripods **30**.

The second building module **120** may be installed directly above the first building module **20**, as shown in FIG. **5**B. FIGS. **4**C and **4**D illustrate a building module **120** having a base **121** comprising steel beams **124** and a concrete floor **122**. During installation of the second building module **120** apertures/holes in the steel beams **124** are located on the locator pins **62** on the locator plates. In other words, the steel beam **24** of the base **121** of the second building module **120** is located on the locator on the tripod **30**. Referring to FIG. **4**D, one of the steel beams **124** is bolted to the angle bracket **40**. In other words, the angle bracket **40** is attached to the second building module **120**.

After the second building module **120** is attached to the angle bracket **40** a permanent support member, such as pre-fabricated concrete wall **80**, is installed and connected to the first building module **20** and the second building module **120**. The permanent support member acts to support at least part of the second building module **120** above the first building module **20**. It is envisaged that the permanent support member could be internal structural walls that are built on site. For example, the internal structural walls could be pre-fabricated concrete walls that are installed after the second building module has been installed.

Referring to FIGS. **5**B to **5**D, the installation process of the second building module and the permanent support structure is shown. As shown in FIG. **5**B, the pre-fabricated concrete wall **82** from the lower level extends halfway between the first building module **20** and the second building module **120**. As shown in FIG. **5**C, a second building module **120** is installed above the first building module **20**. As shown in FIG. **5**D, a pre-fabricated concrete wall **80** is lowered down and placed on top of the pre-fabricated concrete wall **82**. This can be achieved by a crane or a suitable hoist. The upper pre-fabricated concrete wall **80** is

attached to the lower pre-fabricated concrete wall **82** to form a permanent support structure that can be connected to the first building module **20** and the second building module **120**. In other words, the permanent support structure may be formed by one or more pre-fabricated/pre-cast concrete walls/panels.

The permanent support structure is then attached to the first and second building modules **20**, **120** so that the permanent support structure supports the second building module **120**. This may be achieved by, for example, pouring concrete to connect the first building module **20** and the second building module **120** to the permanent support member. Alternatively, the permanent support structure may be bolted to the building modules **20**, **120**, for example through the steel beams **24**, **124**.

As discussed above, the permanent support structure may comprise other forms. For example the support structures may be defined by in situ preparation of core or shear walls using wet concrete that has been poured or sprayed.

Adjacent building modules in a single level can be 'stitched' together, in other words joined together by in situ wet joint connections of concrete, to create a finished floor structure. The in situ formed joints, preferably in the form of beams, are structural joints that contribute to the structural integrity of the building and therefore reduce the amount of vertical support required in the vicinity of the beams. Further information regarding 'stitching' methods can be found in co-pending international patent application no PCT/AU2017/050546, which also claims priority from Australian provisional application no. 2016902460 filed on 23 Jun. 2016 titled "METHODS AND APPARATUS FOR CONSTRUCTING BUILDINGS", and from Australian provisional application no. 2016903025 filed on 1 Aug. 2016 and titled "METHOD FOR CONSTRUCTING A CONCRETE FLOOR IN A MULTISTOREY BUILDING". The description and teachings of that co-pending international patent application is incorporated herein by reference to save reproducing that entire specification herein.

After the permanent support structure is installed the angle bracket **40** is detached from the tripod **30**. This is achieved by rotating the clamp nuts **68** out of position so that the angle bracket **40** is free and remains part of the permanent structure. The height of the tripod **30** is then reduced and the bolts removed from the feet **36**. The tripod **30** is then removed so that the permanent support member supports the second building module **120**. The tripod **30** can then be reused for the next building module. Referring to FIG. **4**E, once the tripods **30** have been removed the façade wall **70** is supported at its lower end by a façade bracket **72** attached to the first building module **20**, and the angle bracket **40** that is attached to the second building module.

Using temporary support structures, such as the tripods **30**, is particularly suitable for tall buildings where concrete walls and columns are needed (smaller buildings can rely more heavily on steel structures), but is still entirely applicable to smaller structures. Suitability can be based on two main reasons: the first being that the building modules require a minimum level of reinforcement and stiffness in order to be transported and/or assembled on site, which later becomes redundant once the concrete walls and columns are in place. The temporary support structures reduce the amount of redundant steel used, thereby making the build more cost effective and more conscious of the environment.

The second reason of the suitability of the presently described method and system is that using temporary support structures decouples the installation of building modules from the installation of the concrete walls and columns, which will often take longer to do as concrete often needs to be poured/sprayed then allowed to set (which can take a week to set).

A benefit of decoupling these processes is that it allows the construction of the building to progress if there are reasons that concrete cannot be poured (due to delays or adverse weather conditions etc.). This can allow a modular building to be completed more quickly by not needing to wait for each level to be fully completed and dried before the modules of the next level can be installed.

It is envisaged that multiple levels could be installed before the permanent support structures are installed. For example, it is envisaged that a build could advance five floors higher than the last permanent support structures before the build would need to stop and wait for permanent support structures to be installed.

It will be understood that in order to decouple the pouring of concrete from the installation of modular building modules on successive level the support members do not need to be temporary support member that are replaced. In other words, the temporary support members could be permanent support members, or they could be support members that become redundant when the building is finished.

FIGS. **1**A to **5**D therefore also illustrate a method of constructing a modular building including the steps of:

a) constructing a base **21** of a first building module **20**;
b) attaching a support member, shown as tripod **30**, to the base **21** of the first building module **20**;
c) installing the first building module **20**;
d) installing a second building module **120** so that at least part of the second building module **120** is supported by the tripod **30**; and
e) installing, after step d), a prefabricated panel between the first building module **20** and the second building module **120** to support the second building module **120**.

Referring to FIG. **5**C, the first building module **20** is part of a first level **100** of the modular building **10** (this could be any floor of the building, not necessarily the 1st floor of the building), and the second building module **120** is part of a second level **102** of the modular building and is located above the first building module. As shown in FIGS. **5**C and **5**D, all of the building modules **20**, **120** for the first and the second levels **100**, **102** are installed before a prefabricated panel between the first building module **20** and the second building module **120** to support the second building module **120**.

As described above, it is envisaged that multiple levels could be installed before the permanent support structures are installed. For example, a second support member, such as a tripod **130**, may be attached to the second building module **120**, and a third building module (not shown) may be installed at the installation location so that at least part of the third building module is supported by the tripod **130**.

In a similar way to that described for the second building module **120**, a permanent support structure can be installed to permanently support the third building module above the second building module. The tripods **130** can then be removed from between the second building module **120** and the third building module. It is also envisaged that the third building module could be installed above the second building module **120** before a permanent support structure such as pre-fabricated concrete wall **80**, or an in-situ poured/sprayed wall, is installed and/or connected to the first and second building modules **20**, **120**, and therefore before the tripods **30** between the first building module **20** and the second building module **120** have been removed.

It is understood that reference to "installing" a permanent support structure includes within its scope both the placement of a prefabricated structure, such as a wall **80**, or the in-situ creation of a permanent support structure by the application of concrete (by pouring or shotcreteing) to create a column, beam or wall.

It is envisaged that instead of attaching a façade wall **70** to the first building module **20** (as described above) a prefabricated concrete wall could also be attached to the first building module **20**. Alternatively, the outer wall could be constructed on site as a shotcrete wall. If a shotcrete wall is desired a bracket for supporting a mesh made from reinforcing steel bar (rebar) may be installed on the first building module **20** to reinforce the concrete wall, either before or after transporting the first building module **20** to the installation location.

FIGS. **6**A to **6**E illustrates a first building module **20** in which the façade wall **70** is replaced by a bracket, shown as rebar bracket **140** and a rebar mesh **150**. The rebar bracket and rebar mesh are used to create a shotcrete wall. The rebar bracket **140** has an elongate body **141** comprising an attaching section **142** and a supporting section **143**. The attaching section **142** and the supporting section **143** are perpendicular and form an L-shaped extruded cross-section. Referring to FIGS. **6**B and **6**E, the supporting section **143** has a supporting means, shown as slots **144**. The slots **144** extend into the supporting section **143** and are open at one end to allow a rebar mesh **150** to be inserted into the slots **144** so that the rebar mesh **150** is supported by the slots **144**. The slots **144** are also angled downwards so that when the rebar mesh **150** is inserted into the slots **144** gravity holds the rebar mesh in the slots **144**.

Referring to FIG. **6**A, two rebar brackets **140** are attached to the angle bracket **40** and the steel beam **24** of the first building module (see above for a more detailed description of the angle bracket **40** and the steel beam **24**). Spacers **145** are used to distance the rebar brackets **140** from the angle bracket **40** and the steel beam **24**. As shown in FIG. **6**A, the rebar mesh **150** is supported between the two rebar brackets **140**. Horizontal sections **152** of the rebar mesh **150** are located in the slots **144** in the rebar bracket **140**. The slots **144** in the rebar brackets **140** are spaced apart so that each of the horizontal sections **152** of the rebar mesh has a corresponding slot **144**.

It is envisaged that splice bars (not shown) made from rebar (splice rebar) could be removably attached to the rebar mesh **150**. The splice bars can have a bent section at one end of the splice bar that allows the splice bar to be hooked onto the rebar mesh **150**. The splice bars could be temporarily attached to the rebar mesh **150** in other ways during transportation (e.g. tied down), however the hooked splice bars provide a quick and easy solution for attachment. The splice bars may be hooked onto the rebar mesh **150** in the warehouse when the rebar mesh **150** is located in the rebar brackets **140**. This ensures that the splice bars are ready to be used on site once the first building module is installed. Alternatively, the rebar mesh **150** and splice bars may be installed once the first building module **20** has been installed at an installation location.

FIG. **6**D illustrates two levels of a modular building, each level having two rebar brackets **140** and a rebar mesh **150**. Once the rebar mesh **150** is installed in the slots of the rebar brackets **140**, the slice bars (not shown) can be removed and used to splice the rebar mesh in the lower level to the rebar mesh in the upper level to form a continuous mesh between the two levels. If another rebar mesh **150** is positioned to the left or right of the rebar mesh **150** shown in FIG. **6**D then the splice bars can also be used to splice together side-by-side sections of rebar mesh. In other words, the splice bars allow adjacent sections of rebar mesh **150** to be spliced together to form a continuous section of rebar mesh.

By using the rebar brackets **140** and the rebar mesh **150** there is no need to weld the rebar mesh **150** to other parts of the partially built building structure (welding is more expensive and time intensive than splicing). This is advantageous as it can reduce the amount of time taken to construct a shotcrete wall. There is also no need for a construction worker to hold and locate the rebar, which is required when attaching mesh rebar in more conventional buildings. This allows larger sections of rebar mesh to be used when utilising the rebar brackets **140**. It is envisaged that the rebar bracket **140** and the rebar mesh **150** could also be used to assist in constructing internal walls. Shutters may also be installed on the module **20** to allow concrete walls to be poured, rather than using a shotcrete process.

While the supporting means is described as slots, it is envisaged that the supporting means could be any other suitable supporting member, such as a hook. In addition, while the rebar mesh **150** has been described as extending between two rebar brackets that extend from the angle bracket **40** to the steel beam **24**, it is envisaged that one or more of the brackets would not extend from the angle bracket **40** to the steel beam **24**, and may be suspended from the angle bracket alone or attached to the steel beam alone. It is also envisaged that instead of the wall being a shotcrete wall, the wall may be a poured wall.

It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

The invention claimed is:

1. A method of constructing a modular multi-storey building, the method comprising:

assembling first and second building modules in a vertical arrangement at an installation location to form a multi-storey building structure, wherein the building modules are fabricated offsite to the installation location at a first location and comprise a base component for forming part of a floor and a façade wall, wherein the façade wall is attached to and supported by a connection extending along a side edge of the base component such that the connection bears the load of the façade wall at the side edge of the base component during transportation from the first location to the installation location, the connection being partially embedded along the side edge of the base component and having a bracket attached to the façade wall such that the façade wall extends vertically upward along the side edge of the base component;

vertically supporting at least part of the second building module above the first building module using temporary support members between the first and second building modules;

installing a permanent support structure between, the first and second building modules to vertically support the second building module above the first building module;

removing the temporary support members; and

installing the permanent support structure after the second building module has been assembled in a vertical arrangement above the first building module at the installation location, wherein installing the permanent support structure includes installing a prefabricated concrete component.

2. The method claimed in claim **1**, including at least partially fabricating the first building module at the first location before assembling the first and second building modules at the installation location.

3. The method claimed in claim **1**, including attaching the temporary support members to the first building module at the first location.

4. The method claimed in claim **1**, including attaching an upper bracket across an upper end of the temporary support members.

5. The method claimed in claim **4**, including attaching the façade wall to the upper bracket.

6. The method claimed in claim **4**, including attaching the upper bracket to the second building module.

7. The method claimed in claim **1**, including assembling a third building module above the second building module before the permanent support structure is connected to the first and second building modules.

8. The method claimed in claim **7**, including assembling the third building module above the second building module using temporary support members.

9. The method claimed in claim **1**, including casting the base component of the second building module to include a steel beam at least partially embedded into the perimeter of the base of the second building module.

10. The method claimed in claim **9**, including locating the steel beam of the base of the second building module on a locator on one or more of the temporary support members.

11. The method claimed in claim **1**, including pouring concrete to connect the first and/or second building module to the permanent support member.

12. The method claimed in claim **1**, including re-using the temporary support members for higher levels of the multi-storey building.

13. The method claimed in claim **1**, including aligning the second building module onto a locator on one or more of the temporary support members, which temporary support members are attached to the first building module.

14. The method claimed in claim **1**, including locating an alignment means at an upper end of the facade wall adapted to align with a second building module above the first building module, the alignment means having an alignment bracket with a channel.

15. The method claimed in claim **14**, including vertically lowering the second building module onto the first building module, such that a locating bracket on the base component of the second building module locates into the channel of the alignment bracket of the first module.

16. A method of constructing a modular multi-storey building, the method comprising: assembling first and second building modules in a vertical arrangement at an installation location to form a multi-storey building structure, wherein the building modules are fabricated offsite to the installation location at a first location and comprise a base component for forming part of a floor and a façade wall, wherein the façade wall is attached to and supported by a connection extending along a side edge of the base component such that the connection bears the load of the façade wall at the side edge of the base component during transportation from the first location to the installation location, the connection being partially embedded along the side edge of the base component and having a bracket attached to the façade wall such that the façade wall extends vertically upward along the side edge of the base component;

vertically supporting at least part of the second building module above the first building module using temporary support members between the first and second building modules;

installing a permanent support structure between the first and second building modules to vertically support the second building module above the first building module;

removing the temporary support members; and

installing the permanent support structure after the second building module has been assembled in a vertical arrangement above the first building module at the installation location, wherein installing the permanent support structure includes creating a concrete component by the in-situ application of concrete.

17. The method claimed in claim **16**, including at least partially fabricating the first building module at the first location before assembling the first and second building modules at the installation location.

18. The method claimed in claim **16**, including attaching the temporary support members to the first building module at the first location.

19. The method claimed in claim **16**, including re-using the temporary support members for higher levels of the multi-storey building.

20. The method claimed in claim **16**, including aligning the second building module onto a locator on one or more of the temporary support members, which temporary support members are attached to the first building module.

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